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SPECIAL SECTION

LED-LIGHTING TEAR-DOWNS
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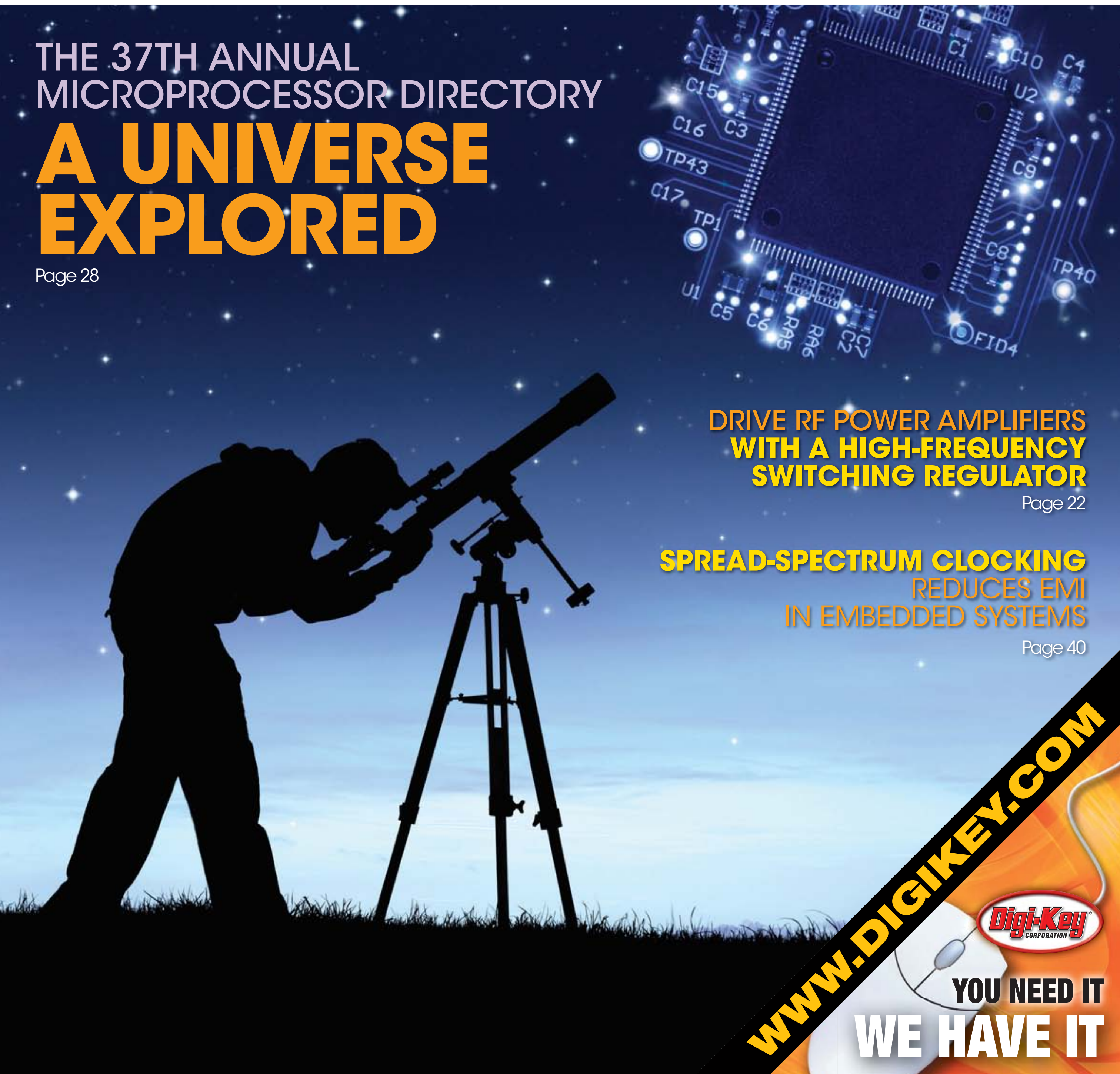

THE 37TH ANNUAL MICROPROCESSOR DIRECTORY

A UNIVERSE EXPLORED

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DRIVE RF POWER AMPLIFIERS WITH A HIGH-FREQUENCY SWITCHING REGULATOR

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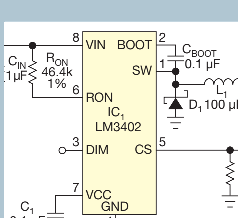

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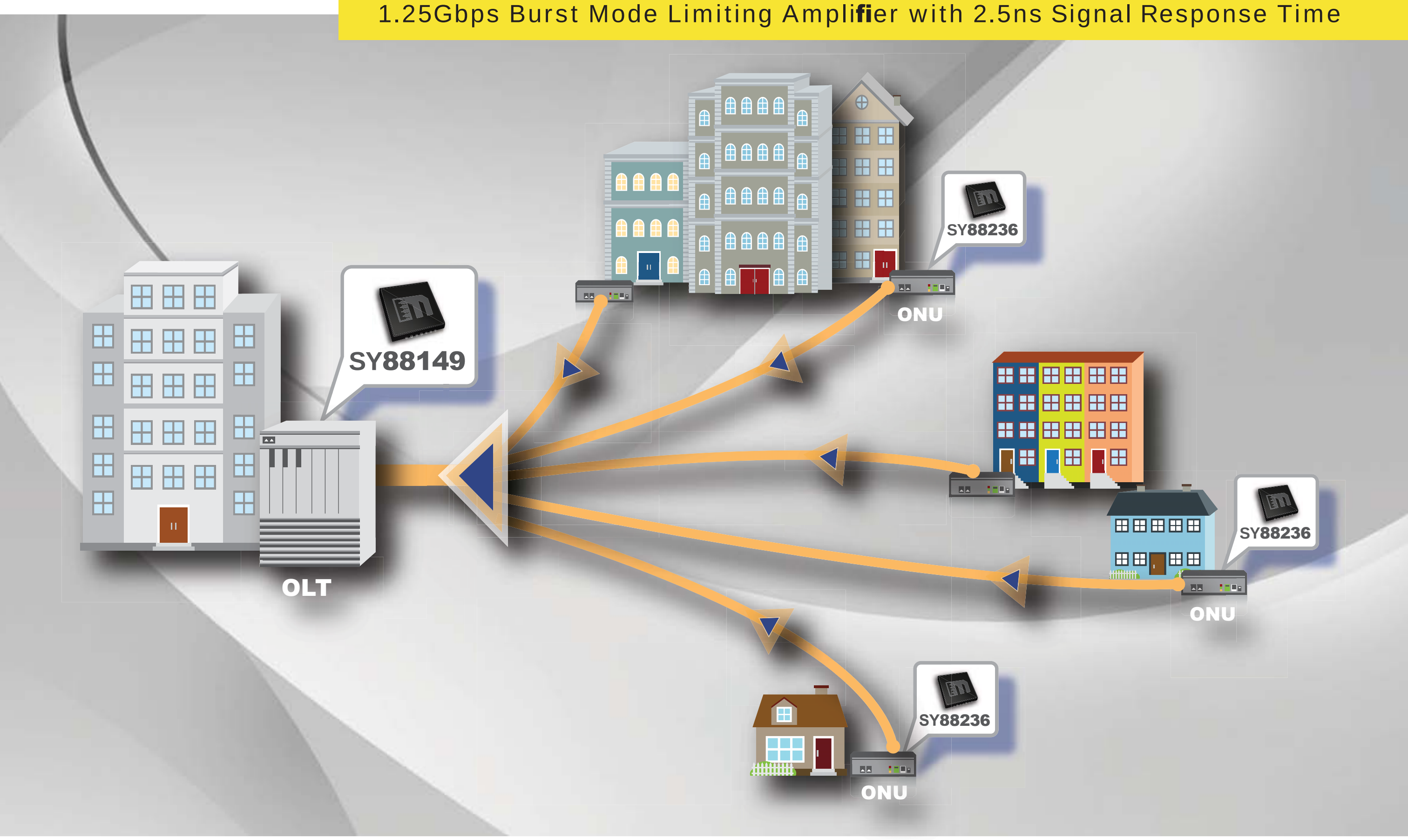
1.25Gbps Burst Mode Limiting Amplifier with 2.5ns Signal Response Time



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For more information, contact your local Micrel sales representative or visit Micrel at: www.micrel.com/ad/SY88149.

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Applications

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DEPARTMENTS & COLUMNS

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High-voltage capacitors suit mission-critical military and aerospace applications
Reconstituted mica paper capacitors often find use in mission-critical military and aerospace applications. When thinking about the testing and design of any high-voltage capacitors, design engineers should consider the two operations as separate but intertwined concepts, with reliability as the goal for both.
→www.edn.com/101007toca

Guest Opinion: Removing the PCB can improve the thermal performance of high-brightness LEDs
Mounting HB LEDs directly on an anodically coated aluminum heat sink improves the thermal path and gets rid of heat, boosting HB-LED efficacy.
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PRYING EYES

In *EDN*'s Prying Eyes, we peer inside an end-user consumer gadget, a reference design, or any other interesting electronics-enabled thing we can get a good look at. Unlike your average bill-of-materials tear-down, Prying Eyes aims to illuminate the tough decisions the engineers responsible for the design had to make.
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Analog Design

EDN's Analog Design Center features news and design information for analog-design engineers, including those working on signal-chain, power, interface, and RF issues. The center also houses Anablog, Technical Editor Paul Rako's blog on analog, the industry, and life in general.
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BY BRIAN DIPERT, SENIOR TECHNICAL EDITOR

Apple's iOS and computing's potential future, Part 1

Shortly before Apple introduced the iPad in January, Steve Jobs, the company's chief executive officer and co-founder, repeatedly noted that the technology would be the most important thing he'd ever done, according to TechCrunch, a group-edited blog about technology start-ups. Coming from someone who has for 35 years had a heavy hand in many of the major innovations in computing, communications, and consumer electronics, those words are thought-provoking. Jobs could simply have meant that he believes that he's come up with the secret sauce for the success of the tablet form factor, which many companies, including Apple itself, have unsuccessfully struggled to develop and commercialize over the past few decades. However, I believe that, as a visionary, Jobs has a broader perspective than a single product category can encompass.

Ponder Apple's history, and you'll frequently encounter the company's overriding desire for complete vertical integration—that is, to own and control all elements of any market in which it participates. Jobs' wishes drive this strategy. Note, for example, that the company licensed its operating system and hardware-patent portfolio to clone-Macintosh manufacturers after ousting Jobs in 1985 and that Jobs quickly shut down the clone program after he returned to power in 1997.

Microsoft's approach with DOS and Windows has, in contrast, historically been more open: a Microsoft-developed operating-system foundation, admittedly, but with a plethora of development tools and published, maintained APIs (application-programming interfaces). Along with Intel's hardware-standardization efforts, this foundation led to today's vibrant and diverse PC ecosystem.

Apple has made a conscious choice over the years to limit its market share, pursuing per-unit higher profit margins instead of higher unit shipments. Nonetheless, the PC ecosystem has also evolved more rapidly—by both increasing features and decreasing prices—than the "closed" Apple counterpart, thereby becoming what today represents a greater-than-90% share domination of the computer market. Interestingly, though, the market share pendulum has over the past few years begun to swing back in Apple's direction, particularly with laptops. This situation has occurred partially because Apple computers now use the same building blocks that PCs use, leading to lower BOM (bill-of-materials) costs and therefore the potential for lower prices.

Back in early 2007, I first discussed another notable factor in the market-share shift (**references 1** and **2**). Consumers paying a certain price for a product understandably prefer more—rather than fewer—features. The inherent danger of adding features, however, is that increasing complexity comes along for the ride, especially when the features come from companies that aren't in lock step with each other. Note, for example, that misbehaving third-party applications and hardware drivers—not Microsoft's operating systems—cause most "blue screens of death."

A large platform-market share, especially in a corporate environment rife with begging-to-be-stolen secrets, also tends to attract the lion's share of folks interested in attacking the software running on that platform. I wager that only a small percentage of you have escaped a malware infestation of your DOS or Windows computer. As a result, an increasing percentage of consumers, seeking simplicity and immunity to viruses, are willing to pay more for

Third-party applications and hardware drivers—not Microsoft's operating systems—cause most "blue screens of death."

an Apple-branded computer that may have fewer features than a comparably priced Windows-powered alternative. With iOS, the ARM-tailored OS X derivative that currently runs on the iPad, iPhone, and iPod touch, Apple can accelerate the transition to Apple products, thereby cementing the company's resurgence. See the next issue of *EDN* for more.EDN

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1 Dipert, Brian, "Consumer limitations with CE gear: Is Apple-like hegemony the way to go?" *EDN*, March 29, 2007, http://bit.ly/bB7X60.

2 Dipert, Brian, "Consumer limitations: the PC exception," *EDN*, April 17, 2007, http://bit.ly/985gt5.

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TI, Semitech target PLC with new kit and chip

PLC (power-line-communication) technology has at least one advantage as a communication channel for Smart Energy and Smart Grid applications: Nonportable appliances are already on the ac mains, so you can use the power lines to communicate power usage and consumption information. Smart meters that communicate with power and water utilities, as well as LANs that monitor and control residential and business appliances and equipment, can benefit from the simplicity of using the available power and transmission lines for communication.

However, PLC technology has had trouble in the past with adequately protected and filtered devices that must contend with the noisy signals that are commonplace on power lines. In addition, the long hauls common in the United States make repeaters necessary, adding to the system cost.

To address these issues, Texas Instruments has introduced the TMDSPLCKIT-V2 PLC-development kit to help developers evaluate the practicality of PLC-based communications for their projects and to jump-start development for Smart Grid applications ranging from smart electrical meters to intelligently controlled industrial applications, including lighting and solar systems and energy-managed systems.

TI based the kit on the company's PLC modem, which comprises a C2000-based microcontroller module and a self-contained, fully isolated analog-front-end module. The kit includes TI's royalty-free plcSuite, a software framework that supports various application and regional requirements. It also features two narrowband PLC modems for communication over low- and medium-voltage power lines with a scalable single-phase data rate to as much as 128 kbps, a power supply, and cables.

The plcSuite software supports all major PLC standards, including the evolving IEC1334 SFSK (spaced-frequency-shift-keying), Prime, and G3, and TI's low-frequency, narrowband FlexOFDM (orthogonal-frequency-division-multiplexing) library. The kit sells for $599.

Also targeting the PLC market, Semitech Semiconductor's new SM2200 power-line transceiver is an OFDMA (orthogonal-frequency-division multiple-access)-based power-line transceiver with 54 carriers and as many as 18 channels. It targets the harsh, noisy environment of wide-area-network transmission lines that smart meters use. The SM2200 has a packet-data modem with a simple physical-layer protocol. The SM2200/microcontroller combination provides a cost-effective approach for data links and point-to-point, star, and ad hoc networks.

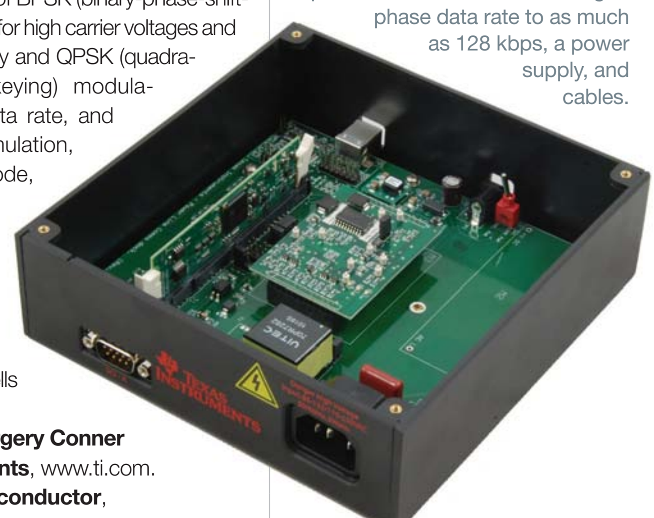
The SM2200 features programmable modulation to improve communications reliability, user-selectable options of BPSK (binary-phase-shift-keying) modulation for high carrier voltages and high noise immunity and QPSK (quadrature-phase-shift-keying) modulation for a high data rate, and a narrowband-emulation, low-frequency mode, putting channels in the CENELEC (European Committee for Electrotechnical Standardization) frequency range. It sells for $4.89 (10,000).

—by Margery Conner

▷**Texas Instruments**, www.ti.com.
▷**Semitech Semiconductor**, www.semitech.com.

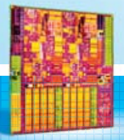
TALKBACK

"TiVo is still alive, and DirecTV has a DVR that allows for instant replay [and] commercial skip. Commercial skipping is alive and well in my living room." —Reader David Hill, in *EDN*'s Talkback section, at http://bit.ly/aZgp0O. Add your comments.



TI's TMDSPLCKIT-V2 PLC-development kit includes the royalty-free plcSuite, two narrowband PLC modems for communication over low- and medium-voltage power lines with a scalable single-phase data rate to as much as 128 kbps, a power supply, and cables.

Intel Embedded Solutions: Medical



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Technical-computing packages gain advanced-signal-processing tools

MathWorks recently announced major new capabilities for designing advanced signal-processing and communications systems with its Matlab and Simulink technical-computing packages. The new SimRF product allows system architects to use Simulink to design and verify complete wireless-communication systems with standard-form RF-subsystem models and advanced circuit-envelope and harmonic-balance methods. An update of the Simulink HDL (hardware-description-language) Coder adds critical-path analysis and area-speed optimizations for automatic HDL-code generation, along with a new Workflow Advisor for FPGA implementations.

Enhancements to the Communications Blockset, Signal-Processing Blockset, and Video-and-Image-Processing Blockset add more than 250 algorithms to Matlab for processing streaming data. MathWorks C-code-generation tools now support the Eclipse IDE (integrated development environment), Embedded Linux, ARM processors, and the SystemC TLM (transaction-level modeling) 2.0 standard.

Together, these new capabilities streamline algorithm design and implementation, enable more advanced system analysis early in development, and provide smooth integration with common tools and standards.

"Engineers need design tools that can simultaneously simulate digital, analog, and software components," says Ken Karnofsky, MathWorks senior strategist. "These new capabilities for signal-processing systems in Matlab and Simulink unify and automate critical tasks in the design workflow."

The innovations include SimRF, which brings circuit-envelope and harmonic-balance simulation techniques to the Simulink environment and provides a large component library for modeling RF-system architectures. SimRF supports multifrequency RF signals for standard-form RF-transceiver representations, diverse interference simulations, and multiport architectures. Communication-system architects can now perform realistic simulations early in development and thus more quickly design, optimize, and verify wireless systems that contain digital and analog baseband and RF subsystems.

SimRF integrates with Communications Blockset and Signal-Processing Blockset to simulate how RF architecture affects communication-system performance. SimRF blocks (orange) model the system's RF architecture. Communications Blockset blocks (green) transmit and receive waveforms. Signal-Processing Blockset blocks (gray) process and analyze signals.

A major update to the Simulink HDL Coder automatically generates VHDL (Verilog HDL) and Verilog code from Simulink models. The Coder now supports rapid design iterations by highlighting critical paths in the model and estimating hardware-resource usage. It also supports optimizations, such as serialization, resource sharing, and pipelining. An FPGA Workflow Advisor automates synthesis and implementation on Xilinx (www.xilinx.com) and Altera (www.altera.com) FPGAs. New verification features include code-traceability support for the DO-254 (defense-oriented) avionics standard.

Enhancements to the Communications Blockset, Signal-Processing Blockset, and Video and Image-Processing Blockset now provide algorithms with a standardized interface to efficiently process audio, video, and other streaming data in Matlab. You can also use the resulting Matlab programs in Simulink to directly create models for system design, simulation, and analysis. These algorithms are available as System objects, a new class of Matlab objects that facilitate algorithm design and reuse.

New support for Embedded Linux, ARM, and the Eclipse IDE enables MathWorks' code-generation products to automate targeting, real-time performance analysis, and C-code verification for Embedded Linux, the ARM Cortex-A8 processor, and Eclipse. The EDA-Simulator Link now supports the generation of SystemC TLM-2.0 components for verification in virtual-platform environments.

The base version of Embedded-IDE Link sells for \$2000, and the Target-Support Package and SimRF sell for \$3000 each. The Simulink HDL Coder sells for \$15,000, and the Communications Blockset, Signal-Processing Blockset, and Video and Image-Processing Blockset cost \$1000 each.

—by Dan Strassberg

▷**MathWorks**, www.mathworks.com.

DILBERT By Scott Adams

DSP touts low power consumption, low price

CPUs with DSP-targeting instruction-set extensions and hardware-acceleration blocks are increasingly able to implement the types of functions that historically required a discrete DSP IC. Look, for example, at the AVX (advanced-vector-extension) enhancements of Intel's (www.intel.com) latest Sandy Bridge microarchitecture, which the company highlighted at last month's Intel Developer Forum, or at the multimedia-processing capabilities of the A4 CPU in Apple's (www.apple.com) iPad.

However, DSPs still have a compelling place in your next system design, claims Denis Labrecque, marketing-programs manager at Analog Devices. Labrecque believes part of the reason is that software developers' processing needs are increasing in lock step with CPUs' capability growth, thereby preserving the stand-alone DSP requirement.

Another part of the reason is the inherently superior determinism of a function-dedicated DSP engine versus a host processor that other system functions might distract at any time. A third part of the reason is that including a discrete DSP chip is an increasingly affordable endeavor.

Take Analog Devices' latest Blackfin BF592, for example. At $3 (10,000) or $3.55 (1000), it runs at 400 MHz, translating to 800 MMAC (million multiply/accumulate) operations/second, and comes in a 9×9-mm LFCSP QFN package. It's no speed screamer, but it won't burn a hole in your bill-of-materials budget, either.

Analog Devices' new Blackfin BF592 DSP sells for $3 (10,000) or $3.55 (1000); runs at 400 MHz, translating to 800 MMAC operations/second; and comes in a 9×9-mm LFCSP QFN package.

The product features lead to some interesting marketing statistics: 88 cents per 100 MHz, 44 cents per 100 MMACs, and 9.87 MMACs/mm^2. The BF592 also offers 4 kbytes of data scratchpad SRAM, 64 kbytes of instruction ROM containing the VDK (VisualDSP++ Kernel) and nearly all of the company's runtime-library code, and 4 kbytes of boot ROM.

Integrated peripherals include a 16-bit PPI (parallel-peripheral interface) that complies with ITU (International Telecommunications Union)-R 656; two serial ports and two SPIs (serial-peripheral interfaces); 32 general-purpose I/Os, and three 32-bit, general-purpose timers. Employing 90-nm-process technology, it operates across a −40 to +85°C extended-temperature range and meets automotive requirements. The advanced lithography combined with low clock speed translates into some fairly impressive power-consumption claims: 300 μA of static-leakage current, less than 1 mW of standby-power consumption, and 88 mW of active-power consumption at 300 MHz.

The BF592 is currently available for sampling. The company is also shipping the $199 ADZS-BF592-EZLite evaluation kit and the $150 ADZS-ICE (in-circuit emulator)-100B.

—by Brian Dipert

▷**Analog Devices**, www.analog.com.

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LED-SIMULATION TOOL BALANCES COST, HEAT, AND SPACE

Designing LED-based lighting requires balancing LED performance, power-control topologies, and thermal-management devices while keeping cost and space requirements in line. The two biggest challenges in LED-lighting design are managing cost and heat. Manufacturers rate their LEDs' luminous efficacy at a certain level at the optimal light output to driving current.

You can drive LEDs to a much higher level and light output, however, allowing you to use fewer LEDs in your system and lower the cost. The downside of this approach is that higher current generates more heat, which lowers the LED's light-generation rate, and the higher current lowers the overall efficiency and power-dissipation effectiveness of the system. Balancing these design trade-offs is a complex mathematical puzzle.

National Semiconductor's free online Webench LED Architect tool allows you to perform quick simulations using the parameters you specify for light output to 100,000 lumens, operating voltages, and ambient temperature. The tool in seconds evaluates LED performance, electronic drive current, and heat compensation and analyzes 350 available LEDs from 12 LED manufacturers, 30 heat sinks from Aavid (www.aavid.com), 35 LED drivers, and a library of 21,000 electronic passive components. The tool also surveys single-quantity prices for the components from various distributors to provide pricing information for low-volume orders. Try the tool at www.national.com/LEDarchitect.

—by Margery Conner

▶National Semiconductor, www.national.com.

RAQ's

Rarely Asked Questions

Strange stories from the call logs of Analog Devices

Watch for Those Multiple Clocking Edges!

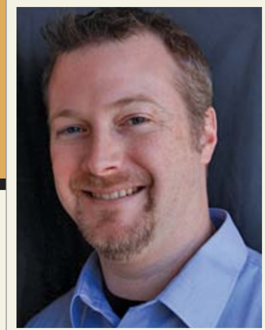
Q. How can I improve system performance when using multiple clocks?

A. A common problem that arises when using multiple clocks generated from the same source is noise—usually a spur popping out of the noise floor—because the single clock source is multiplied or divided into several versions of the same clock. Skewing the adjacent edges of each clock allows you to reduce the noise spur, or get rid of it completely, depending on the system's timing margin. This phenomenon indicates a time-variant system, in which corruption on the clock signal is related to the location of the interference in the time domain. The location of the interference is fixed, so the degree of clock corruption is proportional to the magnitude of the interference, just like in a linear system.

As an example, let's take two outputs of the AD9516 clock generator. One output, at 100 MHz, is connected to an ADC; the other, at 25 MHz ($1/4 \times f_{SAMPLE}$), clocks an FPGA. Rising and falling edges occur on both output clocks at nearly the same time. The result is a coupling effect, because two fast moving, high-bandwidth edges occur every 10 ns instead of one as desired. During this transition period, the noise—intrinsic or extrinsic—must be low, as jitter or noise can only corrupt the ADC's timing when present during the transition region of the clock. Making the edge faster (and hence the threshold region smaller) by increasing the slew rate will inevitably reduce the amount of time that noise can be present during the threshold period, effectively reducing the amount of rms (root-mean-square) jitter introduced to the system. During the steady-state period of the clock—the high and low levels—the clock noise is irrelevant. Therefore, simply delaying either the 25 MHz or 100 MHz clock will spread them apart in time, moving the location of the interference. In other words, arrange for the transition edges of one clock to happen during the steady-state period of the other clock.

In essence, what is happening here is crosstalk-induced jitter (noise) from one trace to an adjacent trace. If one trace carries a signal, and a nearby parallel trace carries a varying current, a voltage will be induced in the signal trace; if it is a clock signal, the time at which the clock edge occurs will be modulated. This causes problems if these edges are taking place at nearly the same time.

To Learn More About Clock Distribution
http://dn.hotims.com/27753-101



Contributing Writer Rob Reeder is a senior converter applications engineer working in Analog Devices high-speed converter group in Greensboro, NC since 1998. Rob received his MSEE and BSEE from Northern Illinois University in DeKalb, IL in 1998 and 1996 respectively. In his spare time he enjoys mixing music, art, and playing basketball with his two boys.

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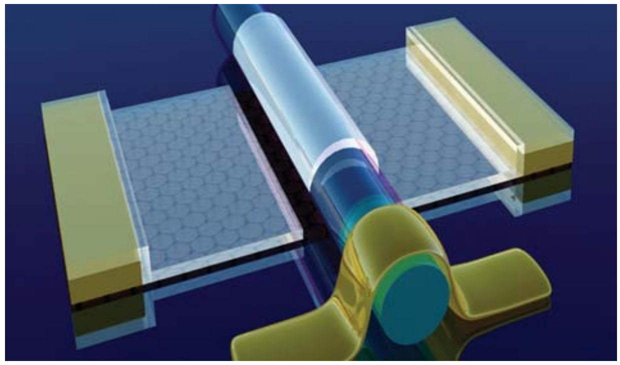
UCLA claims 300-GHz graphene transistors

Researchers and engineers at the University of California—Los Angeles have used a new fabrication method to create what they say is the highest-speed graphene transistors to date, with a cutoff frequency as high as 300 GHz (**Reference 1**). Researchers have in recent years heralded graphene, a one-atom-thick layer of graphitic carbon, as a possible replacement for silicon in semiconductors. The material involves some challenges, however.



UCLA researchers designed this high-speed graphene transistor; the cylinder across the middle of the transistor is the self-aligning nanowire gate (courtesy Xiangfeng Duan Group, UCLA).

Group leader Xiangfeng Duan, professor of chemistry and biochemistry, notes that traditional techniques for fabricating graphene often lead to deteriorations in device quality. The team developed a fabrication process for graphene transistors using a nanowire as the self-aligned gate.

According to Duan, the new strategy produces no appreciable defects in the graphene during fabrication, so it retains high carrier mobility. Second, by using a self-aligned approach with a nanowire as the gate, the researchers overcame alignment difficulties and fabricated very-short-channel devices with unprecedented performance.

The UCLA group notes that the resulting transistors' high cutoff frequency makes them comparable to today's transistors comprising high-electron-mobility materials, such as gallium arsenide and indium phosphide. The group is making additional efforts to scale up the approach and further boost the speed.

Duan worked on the technique with two researchers from the California NanoSystems Institute at UCLA. Yu Huang is an assistant professor of materials science and engineering at the Henry Samueli School of Engineering and Applied Sciences, and Kang Wang is a professor of electrical engineering at the Samueli School. Funding came from the National Science Foundation and the National Institutes of Health.

—by Suzanne Deffree

▷**UCLA**, www.ucla.edu.

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1 Liao, Lei; Yung-Chen Lin; Mingqiang Bao; Rui Cheng; Jingwei Bai; Yuan Liu; Yongquan Qu; Kang L Wang; Yu Huang; and Xiangfeng Duan, "High-speed graphene transistors with a self-aligned nanowire gate," *Nature*, Sept 1, 2010, http://bit.ly/cWydjr.

10.07.10

GEOTEST ADDS LOGIC AND VIDEO-FPGA CAPABILITIES

Geotest is extending its support for FPGAs with the addition of four new logic-interface-expansion modules for its GX3500 FlexDIO 3U PXI (Peripheral Component Interconnect extensions for instrumentation) cards, which incorporate Altera Cyclone III FPGAs. The GX3500 accommodates custom or standard expansion boards that plug in directly as mezzanine cards and require no additional PXI slot.

You can now configure the device with the new GX3501, GX3509, GX3510, and GX3540 logic-interface boards, which provide multichannel interfaces for LVTTL (low-voltage transistor-transistor logic), differential TTL, MLVDS (multipoint-low-voltage differential signaling), and ECL (emitter-coupled-logic) families, respectively. The GX3501, GX3509, and GX3510

Four recently announced logic-interface-expansion modules for Geotest's GX3500 FlexDIO 3U PXI cards provide multichannel interfaces for LVTTL, differential TTL, MLVDS, and ECL families.

feature 80 I/O channels, with each channel independently configurable as an input or an output. The GX3540 features 20 input and 20 output ECL channels with a selectable termination to –2 or –5.2V. The GX3500 can also be preconfigured with a factory-installed expansion board.

Geotest also introduced the GX3671 video-generator board, which the company based on the GX3500. The board supports the generation of 640×480-pixel images for VGA, NTSC (National Television Systems Committee) and PAL (phase-alternating-line) composite video, and S-video formats with 30 bits of color resolution. Users also have full access to the module's FPGA core, providing the flexibility to modify the video generator's parameters or to create custom video signals for specialized video-display or video-processor applications.

The GX3671 comes with a separate video-interface module that supports a variety of video-interface cables, including VGA, S-video, and composite video. Software for the module includes tools for importing and loading bit-map images into the module's video RAM. Base price for the GX3671 is $4290.—by Rick Nelson

▶Geotest, www.geotestinc.com.

DESIGN NOTES

Energy Harvester Produces Power from Local Environment, Eliminating Batteries in Wireless Sensors

Design Note 483

Jim Drew

Introduction

Recent advances in ultralow power microcontrollers have produced devices that offer unprecedented levels of integration for the amount of power they require to operate. These are systems on a chip with aggressive power saving schemes, such as shutting down power to idle functions. In fact, so little power is needed to run these devices that many sensors are going wireless, since they can readily run from batteries. Unfortunately, batteries must be regularly replaced, which is a costly and cumbersome maintenance project. A more effective wireless power solution may be to harvest ambient mechanical, thermal, or electro-magnetic energy in the sensor's local environment.

The LTC3588-1 shown in Figure 1 is a complete energy harvesting solution optimized for high impedance sources such as piezoelectric transducers. It contains a low loss full wave bridge rectifier and a high efficiency synchronous buck converter, which transfer energy from an input storage device to an output at a regulated voltage capable of supporting loads up to 100mA. The LTC3588-1 is available in 10-lead MSE and 3mm × 3mm DFN packages.

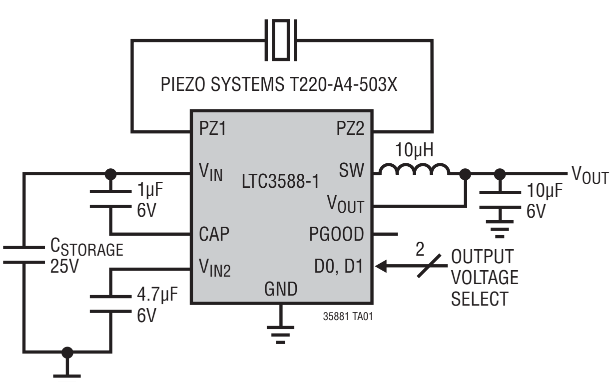

Figure 1. Complete Energy Harvesting Solution Optimized for High Impedance Sources Such as Piezoelectric Transducers

Ambient Energy Sources

Ambient energy sources include light, heat differentials, vibrating beams, transmitted RF signals or any other source that can produce an electrical charge through a transducer. For instance,

- Small solar panels have been powering handheld electronic devices for years and can produce 100s of mW/cm^2 in direct sunlight and 100s of µW/cm^2 in indirect light.
- Seebeck devices convert heat energy into electrical energy where a temperature gradient is present. Sources of heat energy vary from body heat, which can produce 10s of µW/cm^2 to a furnace exhaust stack where surface temperatures can produce 10s of mW/cm^2.
- Piezoelectric devices produce energy by either compression or deflection of the device. Piezoelectric elements can produce 100s of µW/cm^2 depending on their size and construction.
- RF energy harvesting is collected by an antenna and can produce 100s of pW/cm^2.

Successfully designing a completely self-contained wireless sensor system requires power-saving microcontrollers and transducers that consume minimal electrical energy from low energy environments. Now that both are readily available, the missing link is the high efficiency power conversion product capable of converting the transducer output to a usable voltage.

Figure 2 shows an energy harvesting power system that includes the energy source/transducer, an energy storage element and a means to convert this stored energy into a useful regulated voltage. There may also be a need for a voltage rectifier network between the energy transducer and the energy storage element to prevent energy from back-feeding into the transducer or to rectify an AC signal in the case of a piezoelectric device.

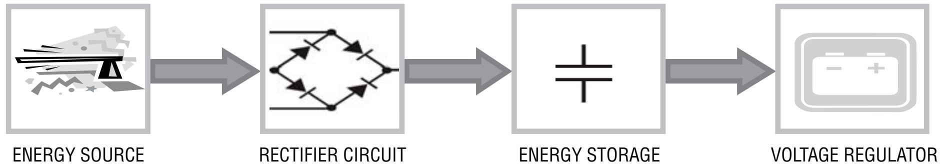

Figure 2. Energy Harvesting System Components

Application Examples

The LTC3588-1 requires the output voltage of the transducer to be above the undervoltage lockout rising threshold limit for the specific output voltage set at the D0 and D1 input pins. For maximum energy transfer, the energy transducer must have an open circuit voltage of twice the input operating voltage and a short-circuit current of twice the input current required. These requirements must be met at the minimum excitation level of the source to achieve continuous output power.

Piezoelectric Transducer Application

Figure 3 shows a piezoelectric system that, when placed in an air stream, produces 100μW of power at 3.3V. The deflection of the piezoelectric element is 0.5cm at a frequency of 50Hz.

Seebeck Transducer Application

Figure 4 shows an energy harvesting system that uses a Seebeck transducer from Tellurex Corporation. A heat differential produces an output voltage that supports a 300mW output load. Connecting the transducer to the PZ1 input prevents reverse current from flowing back into the Seebeck device when the heat source is removed. The 100Ω resistor provides current limiting to protect the LTC3588-1 input bridge.

Harvest Energy from the EM Field Produced by Standard Fluorescent Lights

This application requires some outside-the-box thinking. Figure 5 shows a system that harvests energy from the electric fields surrounding high voltage fluorescent tubes. Two 12” × 24” copper panels are placed 6” from a 2’ × 4’ fluorescent light fixture. The copper panels capacitively harvest 200μW from the surrounding electric fields and the LTC3588-1 converts that power to a regulated output.

Conclusions

The LTC3588-1 allows remote sensors to operate without batteries by harvesting ambient energy from the surrounding environment. It contains all the critical power management functions: a low loss bridge rectifier, a high efficiency buck regulator, a low bias UVLO detector that turns the buck converter on and off, and a PGOOD status signal to wake up the microcontroller when power is available. The LTC3588-1 supports loads up to 100mA with just five external components.

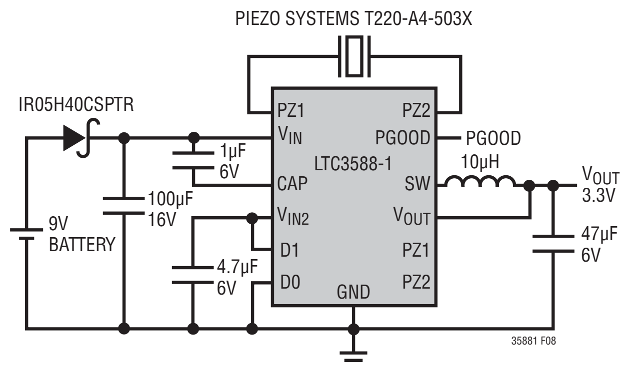

Figure 3. Piezoelectric Energy Harvester

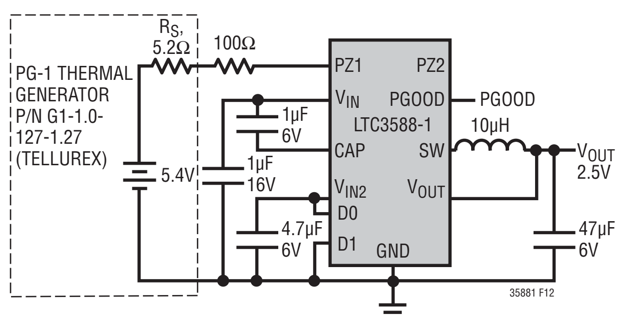

Figure 4. Seebeck Energy Harvester

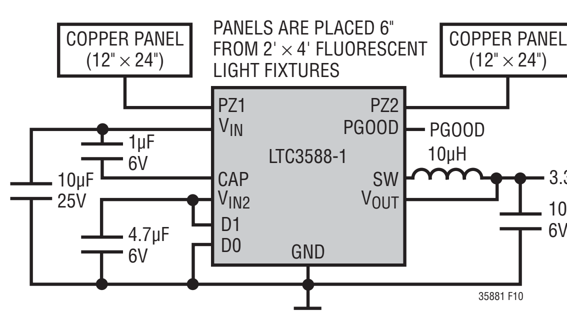

Figure 5. Electric Field Energy Harvester

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BY HOWARD JOHNSON, PhD

Linear superposition

"Imagine a soccer ball," I said to my friend Chris "Breathe" Frue, a talented musician and audio technician who wants to learn more about equalizers, a subject pertaining to both audio and high-speed digital systems. "When you view the ball as a dynamic mechanical system, your kick is a system input. How far the ball goes is a system output."

"The harder I kick, the farther it goes. Is that what you mean?" asked Breathe.

"Right," I replied. "Let's quantify that relation. Suppose that you kick the ball and it goes 50 yards. Then I kick it, and it goes only 40 yards. If we both kick the ball at the same exact moment, what happens?"

Breathe paused. "If we avoid kicking each other and this is not one of your trick questions, then it should go a lot farther than 50 yards, shouldn't it?" he asked.

"Exactly—much farther," I answered. "In fact, if we ignore air resistance and some other technical factors, I expect

it should go about 90 yards. When we superimpose our two inputs, a perfect soccer-ball system superimposes its outputs, creating one big output equal to the sum of the two individual outputs it otherwise would have created. That property is called superposition."

"I still have some questions," Breathe said. "Why can't you play bass and I play flute through the same loudspeaker?"

"If the loudspeaker works properly—and most do at low volumes—it clearly reproduces both sounds," I said. "That's the key idea behind superposition. When superposition holds, you can't tell the difference between two sounds played in consolidated form through a single speaker or the same two sounds played independently through two separate speakers placed side by side. What goes wrong in a practical system is the processing of high-volume signals."

"Like what happens when you turn up your bass until it distorts?" he asked.

"Especially then," I replied. "A bass waveform at high volumes can drive the speaker hard against its end stops. That technique results in a ratty sound, called overdrive, that some people like. A flute superimposed onto a speaker experiencing bass overdrive comes out horribly distorted."

"Give me a concrete example of a system that does obey superposition," Breathe ordered.

"Try the zero function. No matter the input, it puts out zero. Of course, I'm being trivial," I said.

"You are never trivial," he replied. "It seems to me that if I pass the signal X plus Y through your function, the answer comes out zero. By definition, that result equals the result from X, which is zero, plus the result from Y, another zero. Technically, the output signals superimpose, but, if they are all just zero, what's the point?"

"Try a linear scaling function," I responded. "For input X, let the output be KX for some arbitrary constant, K. If you add two signals into the input, you get K times X plus Y. That result is the same as adding together the two results, KX and KY."

"That concept sounds familiar," said Breathe. "Didn't I learn that in fifth grade?"

"Yes. It's the distributed property of multiplication over addition," I said. "Here's another example. Let's say the input to your system is an audio signal—a voltage waveform, X, which varies with time. You can multiply that input signal by any other known function, K, even if K also varies with time, and the result still obeys superposition. That approach works because, at each point in time, the process operates just like a simple scaling function, only the scaling factor, K, changes with time. An RF mixer, for example, might multiply its input by a square-wave carrier. The output appears all chopped up, with many sudden, discontinuous shifts, but, overall, the process still obeys superposition."

"Why does it matter?" Breathe asked.

"Superposition opens the door to the method of analysis by decomposition," I answered. "If I can decompose a complete waveform into a sum of many small parts and if I can calculate the response to each little part, then, in a superimposing system, I can sum all the partial responses to understand how the whole system behaves. This process will make more sense after I describe to you the concept of time invariance." EDN

Howard Johnson, PhD, of Signal Consulting, frequently conducts technical workshops for digital engineers at Oxford University and other sites worldwide. Visit his Web site at www.sigcon.com.

DRIVE RF POWER AMPLIFIERS WITH A HIGH-FREQUENCY SWITCHING REGULATOR

BY MAJID DADAFSHAR • FAIRCHILD SEMICONDUCTOR

USE A DC/DC SWITCHER BETWEEN A SINGLE-CELL LITHIUM-ION BATTERY AND A POWER AMPLIFIER TO GENERATE LESS HEAT AND INCREASE EFFICIENCY AND TALK TIME FOR A GIVEN BATTERY SIZE.

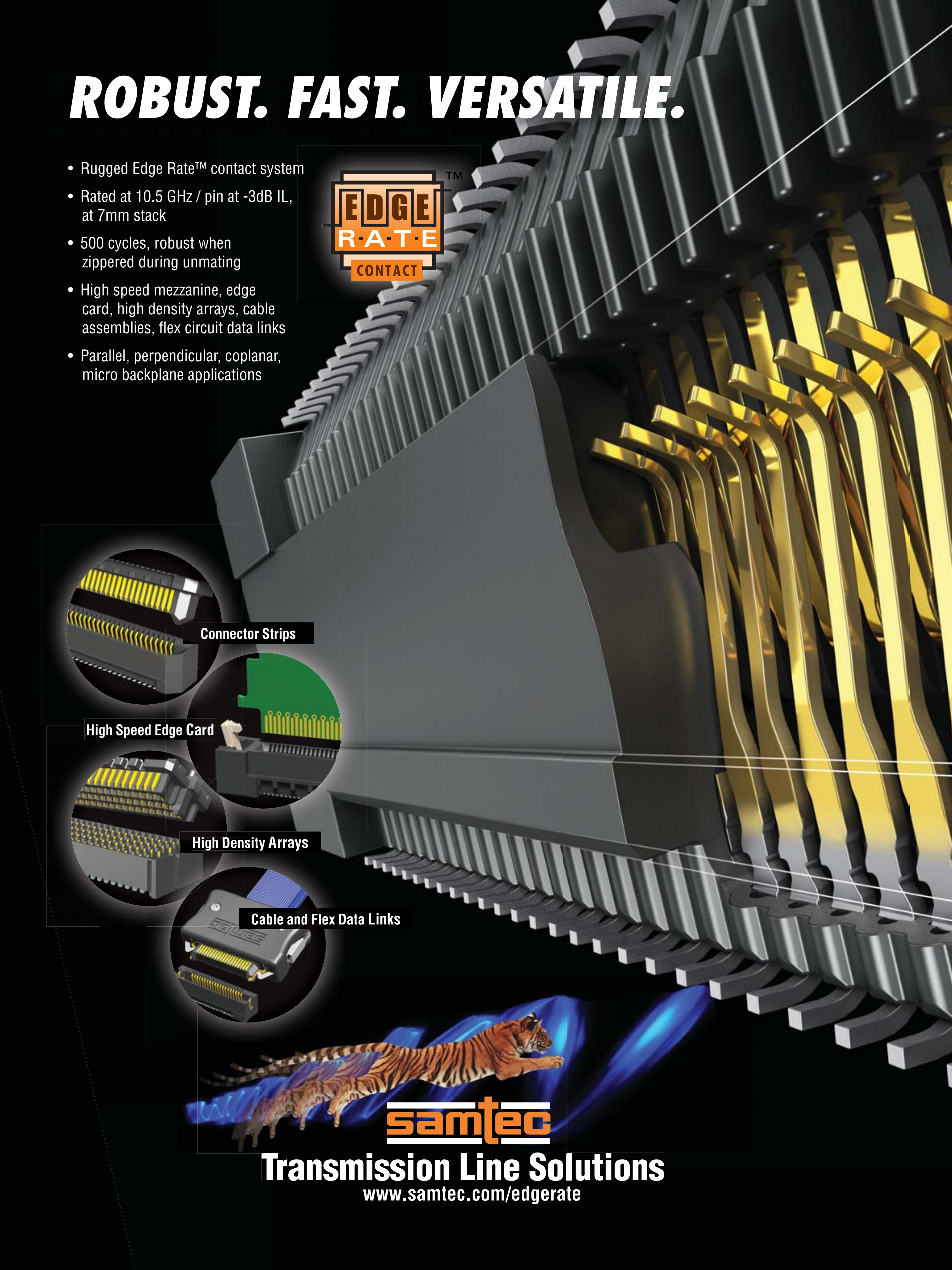
Single-cell lithium-ion batteries traditionally have powered RF (radio-frequency) linear power amplifiers in cell phones. Although the use of these linear power amplifiers can help to meet the specification limits for linearity and ACPR (adjacent-channel power ratio) and ACPL (adjacent-channel power-leakage) ratio, their low power-added efficiency can drain the main battery, cause thermal issues, and reduce talk time. This article aims to demonstrate the benefits of using a dc/dc switcher between the battery and the power amplifier by using dynamic voltage scaling. The resulting increase in efficiency corresponds to less generated heat and increases the talk time for a given battery size.

TABLE 1 USER-EQUIPMENT POWER CLASSES

Power class	Maximum user-equipment output power (dBm/mW)
1	33/2000
2	27/550
3	24/250
4	21/130

RF power amplifiers, whether in 2G TDMA GSM communication, EDGE, or 3G UMTS WCDMA, use linear Class A or Class AB power amplifiers with relatively low efficiency at maximum output power and even lower efficiency at lower output power. When the main battery directly powers these amplifiers during transmitting mode, they draw the most power from the battery in a cell phone. This power consumption effectively depletes the battery and causes a reduction in available talk time. As cellular handsets get more features, such as GPS, cameras, televisions, MP3 players, and e-mail capability, reducing the power draw from the power amplifier can help in the design of handsets with more features and functions.

One of the main challenges designers face with today's mobile handsets is how to design a phone with more features and increase the talk time with same-capacity batteries. Meanwhile, designers must maintain a balance be-


ROBUST. FAST. VERSATILE.
• Rugged Edge Rate™ contact system
• Rated at 10.5 GHz / pin at -3dB IL, at 7mm stack
• 500 cycles, robust when zippered during unmating
• High speed mezzanine, edge card, high density arrays, cable assemblies, flex circuit data links
• Parallel, perpendicular, coplanar, micro backplane applications
EDGE RATE CONTACT ™
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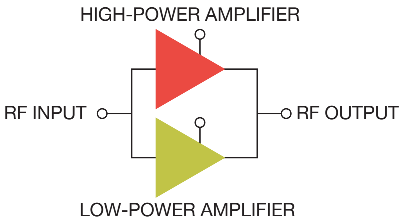

Figure 1 Dual-stage or multistage power amplifiers can have levels for low-, medium-, and high-power transmitting modes and are usually more expensive than a single-stage power amplifier.

tween linearity at high-power mode and efficiency requirements in their new phone designs. Cell phones are usually in Power Class 2. Devices in this class have maximum allowable RF power output of approximately 27 dBm, or 550 mW (**Table 1**).

With 27 dBm, or 550 mW, of output RF power for Class 2 units, the power loss in an amplifier with a power efficiency of 44% is approximately 700 mW; input power is approximately 1.25W. Managing 700 mW of power dissipation within an RF-power-amplifier section is both challenging and costly.

Most WCDMA or EDGE handset phones use multiple modulation schemes to handle higher data rates and spend little time transmitting at full power. However, power-added efficiency at low to medium output power, rather than high-power power-added efficiency, dictates talk time. The quiescent current at low output power and the current consumption at power of 0 to 16 dBm are also important for talk time.

One approach to reducing the power loss within an RF power amplifier is to use a dual-stage design. In this design, each stage obtains the highest efficiency at either low or high power. You can increase the output power of these dual power amplifiers to a desired transmitting power at the beginning of the transmission burst and adjust it back to the low level when the transmission burst ends. Dual-stage or multistage power amplifiers can have different levels for low-, medium-, and high-power transmitting modes and are usually more expensive than a single-stage power amplifier (**Figure 1**).

Integrating two parallel power amplifiers—one for output power greater than 16 dBm and the other for output power less than 16 dBm—can improve the efficiency under both low- and high-power-transmitting conditions and can maintain linearity, with only one switched-on power amplifier. Appropriate load impedance terminates both low- and high-power amplifiers to achieve optimal efficiency in both low- and high-power modes (**Figure 2**).

Traditionally, in multistage RF-power-amplifier designs, the power amplifier directly connects to the battery. A power detector or a coupler samples the signal at the selected interior section of the amplifier and outputs a feedback signal that reflects the power of the signal at that interior section. The baseband-chip processor then adjusts the amplified signal output at a proper power level to maintain the output power within system specifications. Notice that the power-supply level in this approach remains at the same battery-voltage level during all levels of power transmission. Each cellular phone adjusts its RF output power to keep the effective SNR (signal-to-noise ratio) at the base station the same for each phone.

AT A GLANCE

- Low power-added efficiency in single-cell lithium-ion batteries can drain cell phones' main battery, cause thermal issues, and reduce talk time.
- One approach to reducing the power loss within an RF power amplifier is to use a dual-stage design, in which each stage achieves the highest efficiency at either low or high power.
- Integrating two parallel power amplifiers can improve the efficiency under both low- and high-power transmitting conditions and can maintain linearity.
- Meeting a specification of approximately –39 dBc helps to improve voice quality and minimize the power amplifier's distortion, which causes interference with neighboring radio channels.

The addition of the coupler is a direct indication of the output signal, but it requires the insertion of a component in series with the output signal, resulting in reduced power-added efficiency. When the impedance of the amplifier load is improperly matched, the coupler or power detector measures a voltage that could have some errors and does not accurately predict the output power.

An alternative to using battery voltage to supply the amplifier's common-cathode voltage to improve the power amplifier's efficiency is to use a dc/dc switching converter with dynamic voltage scaling to supply the optimal voltage to the amplifier (**Figure 3**). Power-added efficiency is a ratio of the RF output power to the sum of the dc power and RF input power, which you can see when the power amplifier connects directly to the battery, versus a scenario in which the output of a dc/dc switcher replaces the dc power. Lowering the output voltage of the dc/dc switcher yields an increase in the amplifier's overall efficiency. This step reduces output current, which the power amplifier draws, and results in a lower input current draw from the battery due to the dc/dc converter's inherent

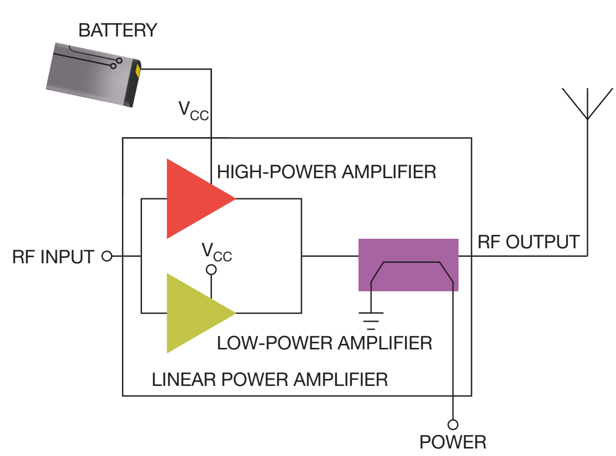

Figure 2 An appropriate low impedance terminates both low- and high-power amplifiers to achieve efficiency at both low- and high-power modes.

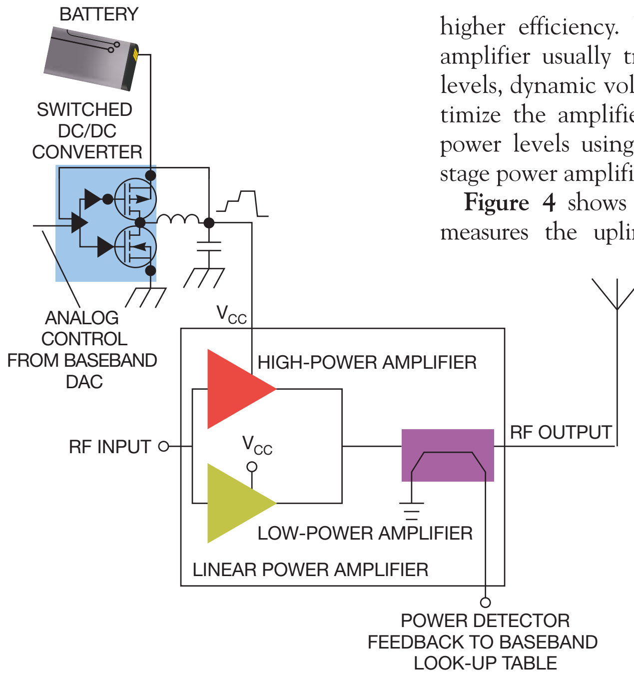

Figure 3 Instead of using battery voltage to supply the amplifier's common-cathode voltage, you can use a dc/dc switching converter with dynamic voltage scaling to supply the optimal voltage to the amplifier.

higher efficiency. Because any power amplifier usually transmits low power levels, dynamic voltage scaling can optimize the amplifier's efficiency at all power levels using a low-cost, single-stage power amplifier.

Figure 4 shows how a base station measures the uplink- and downlink-signal strength from the handset and forces the handset to find an appropriate DAC output from the look-up table to drive the control voltage, which enters the dc/dc switching regulator and therefore adjusts the power amplifier's common-collector voltage for optimal efficiency. With dynamic voltage scaling, the output voltage must vary as the transmitted power levels change to meet the ACPR/ACPL specification. ACPR/ACPL is the ratio of the power spectral density of the main channel to the power spectral density at several offset frequencies.

Meeting a specification of approximately –39 dBc helps to improve voice quality and minimize the power amplifier's distortion, which causes interference with neighboring radio channels. In this approach, when the base station commands the handset to change the transmitted output radio frequency based on the measured signal from

LOWERING THE OUTPUT VOLTAGE OF THE DC/DC SWITCHER YIELDS AN INCREASE IN THE AMPLIFIER'S OVERALL EFFICIENCY.

the phone, the handset processor adjusts the RF power into the amplifier by changing the analog control signal from the baseband DAC to obtain the best RF-power-amplifier efficiency.

Buck regulators require several key features to power an RF-power-amplifier section. First, the power amplifier most often operates in the 5- to 10-dBm, or 3.2- to 10-mW power level—not 27 dBm, or 550 mW. Therefore, a useful target for improving amplifier efficiency is to use a dc/dc switching regulator with high efficiency over a wide load range. Buck regulators must also have switching frequencies greater than 6 MHz, depending on the frequency band. This frequency can minimize the effects of harmonics on the RF bands (**Table 2** and **Figure 5**).

Third, the bypass FET (field-effect transistor) must have an on-resistance of less than 35 mΩ. When the battery is low and the dc/dc switcher goes into a bypass mode, a low-on-resistance bypass FET allows full usage of the lithium-ion battery. The buck regulators also must exhibit duty-cycle operation of 10% for output voltages of 0.4V and low spurious signals.

The operating frequency of 6 MHz corresponds to lower spurious noise than that of lower-operating-frequency regulators. Dynamic-output-voltage adjustment allows better efficiency by adjusting the output voltage of the regulator based on the RF output power (**Figure 6**).

Fast turn-on is also important. When using a dc/dc switching converter to power the RF power amplifier, the key transient parameter is the control-voltage transient, which changes the output voltage from a low value to a higher value, or vice versa, without undershoots or overshoots and within the target time (**Figure 7**).

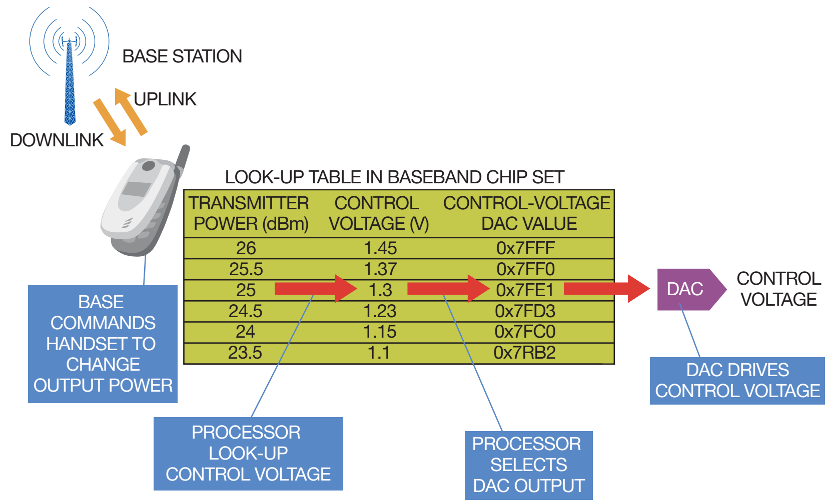

Figure 4 A base station measures the uplink- and downlink-signal strength from the handset and forces the handset to find an appropriate DAC output from the look-up table to drive the control voltage, which enters the dc/dc switching regulator and therefore adjusts the power amplifier's common-cathode voltage for optimal efficiency.

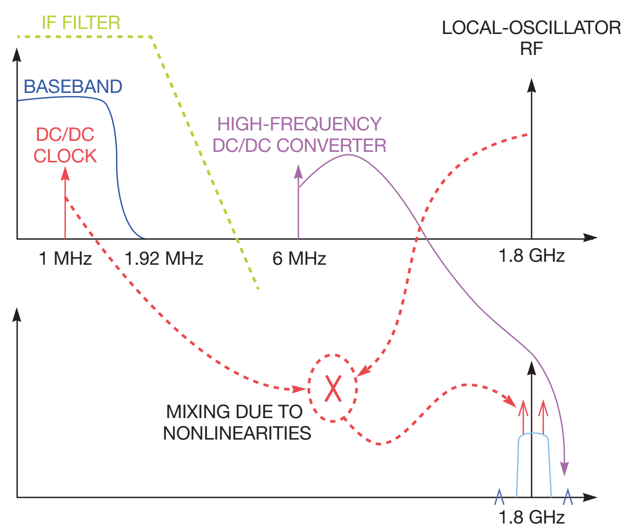

Figure 5 A frequency greater than 6 MHz can minimize the effects of harmonics on the RF bands.

TABLE 2 FREQUENCY-BAND RATES

Frequency band	**Uplink** (MHz)	**Downlink** (MHz)
1	1920 to 1980	2110 to 2170
2	1850 to 1910	1930 to 1990
3	1710 to 1785	1805 to 1850
4	1710 to 1755	2110 to 2155
5	824 to 849	869 to 894
6	830 to 840	875 to 885
7	880 to 915	925 to 960

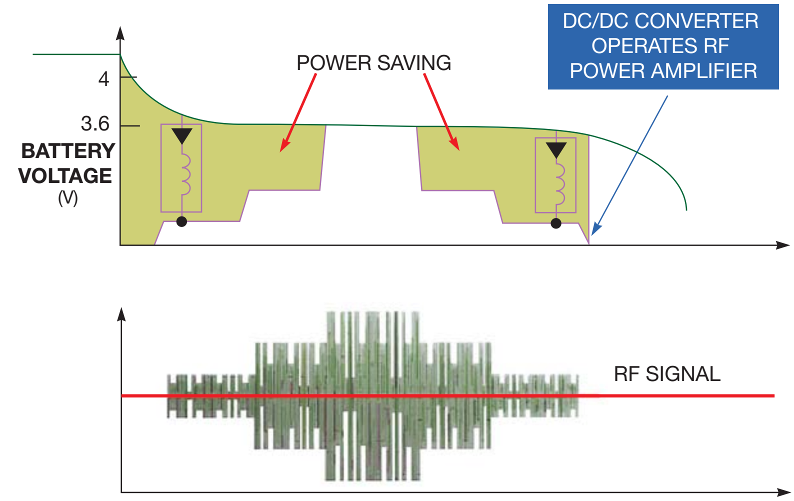

Figure 6 Dynamic output-voltage adjustment allows better efficiency by adjusting the output voltage of the regulator based on the RF output power.

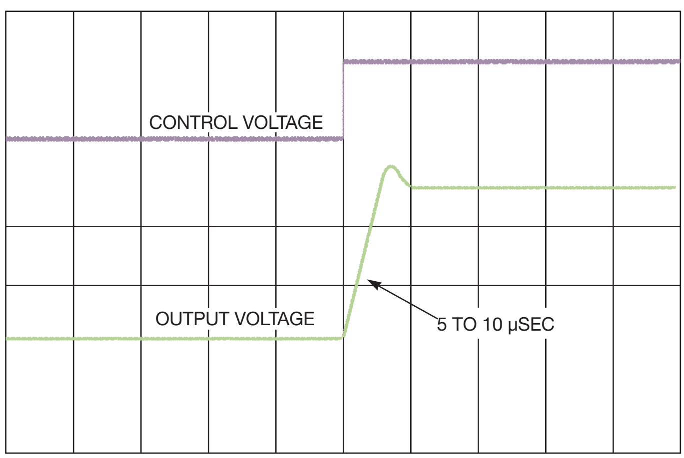

Figure 7 When using a dc/dc switching converter to power the RF power amplifier, the key transient parameter is the control-voltage transient, which changes the output voltage from a low value to a higher value, or vice versa, without undershoots or overshoots and within the target time.

Many cell-phone designs use single-stage RF power amplifiers with the battery as the supply rail. Adding dynamic voltage scaling to the RF power amplifier's supply rail is another effective way to increase the power-added efficiency, reducing the generated power loss within an RF section and increasing the talk time for a lithium-ion battery using a single-stage, low-cost power amplifier. Integrating the dynamic-voltage-scaling switching regulator with a multistage RF power amplifier is another approach. **EDN**

AUTHOR'S BIOGRAPHY

Majid Dadafshar is a field-application engineer at Fairchild Semiconductor. He has more than 25 years' worth of design-engineering experience in power electronics, both in commercial and military applications, and has worked at ITT Power Systems, ITT Courier, ITT Aerospace/Defense, Sony Electronics, Eastman Kodak, and Pulse Engineering. Dadafshar received a bachelor's degree in engineering in 1984 from Northern Arizona University (Flagstaff, AZ). He holds four patents and has published a number of technical papers on power-supply designs, electromagnetic interference, loop stability, and other topics. He has also conducted numerous domestic and international electronic technical meetings.

The 37th annual microprocessor directory

A UNIVERSE EXPLORED

BY ROBERT CRAVOTTA • EMBEDDED INSIGHTS

DON'T LET THE PERFECT PROCESSOR DISAPPEAR JUST BECAUSE MANUFACTURERS ARE PACKING MORE FEATURES FOR LESS COST AND LOWER POWER.

Even after 37 years of documenting the companies and their processors that target embedded-system applications, the annual *EDN* Microprocessor/Microcontroller Directory continues to grow. Companies each year continue to launch software-programmable processor architectures in an attempt to enable embedded-system developers to build applications with lower prices and smaller energy budgets yet deliver more features than ever before. Since the 36th edition of the directory, several companies have launched processors that have paved the way to even lower power consumption and prices.

This directory represents an effort to collect all of the processing options available to embedded-system developers and help them quickly narrow the list of candidate processors for their projects. *EDN* is constantly uncovering companies that did not exist or participate in previous editions of the directory. If you notice an overlooked company, please let that company and us know that you missed them and would like to see them in the directory. If this directory helps you find or choose a device or core, please let the vendor know how you found its part.

The print version of this directory is but a small excerpt of the online directory, which comprises hundreds of pages of material. You can visit the full online version of the Embedded Processing Directory at www.embeddedinsights.com/directory. The online material is updated on a regular basis as new processors become available.

ACTEL

Actel (www.actel.com) offers low-power and mixed-signal flash FPGAs. Actel flash FPGAs support ARM and 8051 processors, including a license- and royalty-free, 32-bit, FPGA-optimized ARM Cortex-M1 soft processor as well as a hard-gate, 100-MHz, 32-bit Cortex-M3 on Actel's SmartFusion intelligent mixed-signal FPGA. Actel's low-power ProASIC3L FPGAs feature 40 and 90% lower dynamic and static power, respectively, than the company's ProASIC3 FPGAs.

ADVANCED MICRO DEVICES

AMD (Advanced Micro Devices, www.amd.com) processors support scalable, x86-based, low-cost, and feature-rich products and energy conservation. AMD introduced the Opteron 4000 Series platform for enterprise-class embedded systems, such as networking and storage devices, as well as the compact ASB (advanced-system-bus) 2 and high-performance AM3 platforms for embedded systems spanning industrial controls to digital signage, point-of-sale, and kiosk systems.

ALTERA

Altera (www.altera.com) offers programmable products targeting communications, industrial, military, imaging and video, and test applications. Products include CPLDs, FPGAs, and HardCopy ASICs, as well as embedded processors and development tools. The 32-bit Nios II soft embedded processors feature three configurations trading processing performance and core size. Altera also supports third-party processor options from leading embedded-processor vendors for use in its devices.

ALTIUM

Altium (www.altium.com) provides next-generation electronics-design software. Altium Designer supports interactive FPGA-system design for vendor-independent electronic-product development using soft, hybrid, and discrete processors. It includes a number of royalty-free 8- and 32-bit, FPGA-based soft processors, such as the 8051, Z80, PIC, and FPGA-independent TSK3000 core. The software features support for processors, such as ARM7, Nios II, and Microblaze.

ANALOG DEVICES

Analog Devices' (www.analog.com) ADuC precision analog microcontrollers combine ARM7 or 8052 microcontroller cores with integrated precision converters, references, and sensor peripherals to target automation, industrial, and automotive applications. Blackfin processors combine signal-processing capabilities with control functions in a single 16/32-bit core. Target applications include audio and video consumer products, medical electronics, video surveillance, VOIP (voice over Internet Protocol), and industrial instrumentation and control.

APPLIED MICRO CIRCUITS CORP

AMCC (Applied Micro Circuits Corp, www.amcc.com) offers embedded Power Architecture processors targeting control-plane, imaging, wireless-access, industrial-control, storage, and networking applications. Applied Micro offers hardware- and software-reference designs to help designers in the wireless-access-point and the ATCA (Advanced Telecom Computing Architecture) AMC (advanced-mezzanine-card) market. The Titan core uses Intrinsity's Fast14 logic to reach clock speeds as high as 2 GHz at 2.5W, and it supports coherent multiprocessing.

ARM

ARM (www.arm.com) licenses semiconductor IP (intellectual property), including processors, peripherals, interconnect, and physical libraries targeting mobile, automotive, consumer-entertainment, imaging, networking, storage, security, and wireless applications. The company's range of processors includes the ARM7, ARM9, ARM10, and ARM11 families and the Cortex family featuring Thumb-2 technology. ARM also offers the SecurCore processor family, the Mali family of graphics processors, TrustZone technology, and Jazelle execution-environment-acceleration software.

ASIX ELECTRONICS

ASIX Electronics (www.asix.com.tw) offers non-PCI (Peripheral Component Interconnect)-Ethernet controllers, USB (Universal Serial Bus) 2.0-to-Ethernet NIC (network-interface-card) controllers, and network SOCs (systems on chips) targeting embedded-networking applications, such as home appliances, factory/building automation, industrial equipment, security systems, remote-control/monitoring/management, and streaming-media applications.

ATMEL

Atmel (www.atmel.com) offers microcontrollers and microprocessors employing its proprietary 8- and 32-bit AVR and ARM's Cortex-M3, ARM7, and ARM9. Over the previous year, the company introduced the ATtiny4/5/9/10 in a package measuring 2×2 mm. The 32-bit pico Power AVR UC3L supports 165 μA/MHz operation in active mode; power ranges to 9 nA with all clocks stopped. Atmel QTouch Library and Atmel QTouch Studio expand and support all AVR microcontrollers.

AUSTRIAMICROSYSTEMS

austriamicrosystems (www.austriamicrosystems.com) offers high-performance analog ICs with a focus on power management, sensors and sensor interfaces, and portable audio. The company's ARM922T-based AS3524/25/27 analog integrated-microcontroller ICs combine strong calculating power, high-performance-audio features, and system-power-management options for battery-powered devices.

BEYOND SEMICONDUCTOR

Beyond Semiconductor (www.beyondsemi.com) licenses two families of 32-bit processor cores as Verilog RTL (register-transfer-level). All processors include Linux and eCos operating-system support. The superscalar BA14 features dual-issue, out-of-order execution. With DSP instructions and an optional double-precision floating-point unit, it targets applications with demanding performance requirements.

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BROADCOM

Broadcom's (www.broadcom.com) integrated processors target data-networking and communications applications, as well as security, storage, 3G (third-generation)-wireless infrastructure, and high-density computing. The Broadcom broadband CMP (chip-multiprocessing) systems integrate as many as four 64-bit MIPS processor cores onto a single die.

CAMBRIDGE CONSULTANTS

Cambridge Consultants' (www.cambridgeconsultants.com) XAP4 and XAP5 processor soft-IP (intellectual property) cores target applications such as wireless sensors, and their architecture minimizes the size of program and data memories to achieve small die area, especially when memory is embedded on-chip or integrated in an SIP (system in package).

CAST

Cast (www.cast-inc.com) offers IP (intellectual-property) cores for general-purpose 8-, 16-, and 32-bit processors. A configurable 8051 core executes instructions with one clock per cycle. Additional cores include 8-bit Z80 and 16-bit 68000- and 80186EB-compatible devices. Cast's 32-bit APS cores require as few as 7000 gates, perform at 0.6 Dhrystone MIPS/MHz, and use as little as 18 μW/MHz of power.

CAVIUM NETWORKS

Cavium Networks' (www.caviumnetworks.com) processors target intelligent processing for networking, communications, and digital homes. Cavium Networks offers integrated, software-compatible processors ranging in performance from 100 Mbps to 40 Gbps that enable secure, intelligent functions in enterprise, data-center, broadband/consumer, access, and service-provider equipment.

CIRRUS LOGIC

Cirrus Logic (www.cirruslogic.com) supplies high-precision analog- and mixed-signal and embedded processors for the audio and industrial markets. In the general-purpose-processor segment, Cirrus Logic offers highly integrated ARM9- and ARM7-based embedded processors targeting industrial and networked consumer applications.

COREWORKS

Coreworks' (www.coreworks.pt) five-stage-pipeline, modified-32-bit-Harvard-architecture FireWorks features a high-speed programming interface and DSP instructions. The programming interface is accessible using the Core Access Networks infrastructure, which includes FaceWorks, a network-interface core, and the RAL (remote-access library), a software package for building remote data-exchange and -control applications.

CPU TECHNOLOGY

CPU Technology (www.cputech.com) offers multicore SOC (system-on-chip) devices as well as development tools that target computers and peripherals, communication/wired, general-purpose, imaging and video, industrial, medical, military/aerospace, mobile/wireless, and test-and-measurement applications. The Acalis family of field-programmable multicore chips provides security functions that protect IP (intellectual property) without affecting performance.

CYAN TECHNOLOGY

Cyan Technology's (www.cyantechnology.com) low-power, 16-bit, embedded-communications, flash-based eCOG1k microcontroller implements a 25-MHz RISC Harvard architecture that includes internal flash memory, RAM, and cache. The external-memory interface supports addressability of 32 Mbytes of external memory.

CYBERNETIC MICRO SYSTEMS

Cybernetic Micro Systems (www.controlchips.com) produces ASICs to interface to peripherals. The 100-pin, 8-bit P-51 microcontroller either sits between the host computer and the peripheral device or becomes the peripheral device. With a dual-port RAM interface on the host side

in a PC104/ISA (industry-standard-architecture) format, the P-51 looks like memory to the host, but it has the intelligence and capability of an 8051.

CYPRESS

Cypress' (www.cypress.com) PSoC (programmable system on chip) integrates configurable digital and analog peripherals, an 8- or 32-bit microcontroller, and three types of embedded memory. This year, Cypress introduced the 8051-based PSoC 3 and the ARM Cortex-M3-based PSoC 5 architectures. The new second-generation TMA300 PSoC-based TrueTouch touchscreen-controller family can simultaneously interpret as many as 10 inputs.

DIGI INTERNATIONAL

Digi International (www.digi.com) offers net-centric Net+ARM processors based on ARM7 and ARM9 cores. Digi supports development for the 32-bit Net+ARM microprocessor with its royalty-free Net+OS advanced networking software, development tools, and real-time operating system. Support for Linux and Microsoft Windows Embedded CE 6.0 is available.

DIGITAL CORE DESIGN

DCD (Digital Core Design, www.dcd.pl) provides VHDL- and Verilog-synthesizable, ISO 9001:2000-certified IP (intellectual-property) cores of 8-, 16-, and 32-bit processors and bus interfaces, as well as fixed- and floating-point arithmetic co-processors. The company's DP8051XP/DP80390XP soft core is 100%-binary-compatible with the industry-standard, 8-bit 8051 microcontroller. DCD's microcontrollers implement fast 16- and 32-bit integer operations and single- and double-precision floating-point operations.

E2V

E2V's (www.e2v.com) microprocessor products range from the 68K family to PowerPC devices and support peripherals. In addition to test and service facilities, the company offers long-term availability on the complete family of products. The high-reliability products comply with the AS/

EN 9100 aerospace standard and the AQAP 2110 military standard.

EM MICROELECTRONIC

EM Microelectronic (www.emmicroelectronic.com) offers ultra-low-power, low-voltage digital-, analog-, and mixed-signal ICs targeting battery-operated and field-powered devices in consumer, automotive, and industrial applications. EM Microelectronic's 4- and 8-bit microcontrollers target battery-operated devices, such as fire alarms, medical-monitoring devices, sports-activity monitors, radio-controlled clocks, intelligent sensors, data loggers, metering devices, intelligent terminals, card readers, measurement devices, and scales.

ENERGY MICRO

Energy Micro (www.energymicro.com), a fabless semiconductor company, offers 32-bit microcontrollers that consume ultralow power. New processor products include the ARM Cortex-M3-based EFM32 Gecko microcontroller family and the EFM32 Tiny Gecko product family. The EFM32 consumes less than 180 μA/MHz while executing real-life code from flash. Its standby current consumption is typically 900 nA when running a real-time clock, power-on reset, brownout detection, and full RAM and CPU retention and less than 20 nA in its deepest sleep mode.

ENSILICA

EnSilica (www.ensilica.com) offers a portfolio of IP (intellectual property), including the eSi-RISC family of highly configurable 16- and 32-bit embedded processors, the eSi-Comms range of communications IP, and cryptographic and processor-peripheral IP. The eSi-RISC family includes the 16-bit eSi-1600, the 32-bit eSi-3200, and the 32-bit eSi-3250 processors. The processor cores benefit from selectable Harvard/von Neumann memory and configurable-cache options.

FREESCALE SEMICONDUCTOR

Freescale Semiconductor (www.freescale.com) offers communications and embedded processors, sensors, RF components, and analog/power-management technology for automotive, consumer, industrial, and networking applications. The PowerQUICC (quad-integrated-communications-controller) and QorIQ processors target data- and control-plane processing for wireless and wire-line infrastructure, industrial control, enterprise networking, and home and SOHO (small-office/home-office) networking markets. Freescale this year introduced the 2.5-GHz, 64-bit e5500 core; the quad-core P3041 processor; new P1 and P2 QorIQ processors; and Kinetis ARM Cortex-M4 and ColdFire+ microcontrollers.

FUJITSU SEMICONDUCTOR AMERICA

Fujitsu Semiconductor America (www.fujitsu.com) offers 8-, 16-, and 32-bit microcontrollers, including general-purpose and application-specific versions. Most of the microcontrollers include onboard-flash, ROM, ADC, DAC, CAN (controller-area-network), USB (Universal Serial Bus), and LCD controllers to target automotive, communications, computer-peripheral, industrial, and consumer applications.

GAINSPAN

GainSpan (www.gainspan.com), a provider of low-power, embedded-Wi-Fi semiconductor and software, offers SOCs (systems on chips) with flash memory, SRAM, and a processor in a single package; embedded and serial-to-Wi-Fi software; and integrated development environments with a hardware-debugging interface and enterprise-level 802.11b/g certification. GainSpan embedded Wi-Fi finds use in mobile/wireless, industrial, and medical applications.

HYPERSTONE

Hyperstone (www.hyperstone.com) offers the general-purpose E1 processors, the HyNet networking processors, and NAND-flash controllers that the company based on a unified RISC/DSP architecture. Manufactur-

ing tools for the S7(B) and F4 NAND-flash-memory controllers include reference designs, development utilities, and operating firmware that implements Hyperstone's patented flash-management techniques.

IBM

IBM Global Engineering Solutions (www.ibm.com) offers the 32-bit PowerPC 4xx family of embedded cores, along with 32- and 64-bit power- and performance-optimized microprocessors. IBM's PowerPC 405, 440, and 460 families of embedded cores offer scalable performance for custom-SOC (system-on-chip) integration. The cores are available in both fab-optimized and fully synthesizable versions.

IMEC

Imec's (www.imec.be) flexible ADRES (architecture for dynamically reconfigurable embedded system) comprises a tightly coupled VLIW (very-long-instruction-word) processor and a coarse-grained, reconfigurable array. The architecture includes computational, storage, and routing resources in a topology to form the ADRES array. A script-based technique allows designers to generate instances for the communication topology, supported operation set, resource allocation, and timing of the target architecture.

IMSYS

Imsys (www.imsystech.com) develops reconfigurable-processor platforms that accept programs written in Java, C/C++, assembler, and microcode. The company offers Internet-enabled reference modules with complete operating- and file-system environments. The integrated hardware and software platform targets wired and wireless communications; graphics-display technologies; and image processing in telecom, automotive, industrial automation, and consumer electronics.

INFINEON TECHNOLOGIES AG

Infineon Technologies AG (www.infineon.com) provides 8-, 16-, and 32-bit microcontrollers for automotive- and industrial-control systems with dedicated hardware peripherals. Infineon introduced the 32-bit Audo Max family for automotive-power-train and -chassis applications. Infineon added high- and low-end derivatives to the XE166 and XC2000 families of 16-bit digital-signal controllers. The company introduced 8-bit devices that operate at ambient temperatures as high as 150°C. Infineon also introduced the low-cost, low-pin-count, 8-bit XC82x and XC83x microcontroller families.

INNOVASIC SEMICONDUCTOR

Innovasic Semiconductor (www.innovasic.com) supplies extended-life microcontrollers for industrial applications. The 32-bit fido1100 communications controller targets real-time Ethernet applications with silicon-embedded RTOS-like features, including single-cycle task switching, scheduling, and programmable peripherals. Innovasic supplies 16-bit 186 microcontrollers for new and legacy applications. All Innovasic products come with an obsolescence-protection guarantee.

INTEGRATED DEVICE TECHNOLOGY

The IDT (Integrated Device Technology, www.idt.com) Interprise family of integrated communications processors delivers data processing at line-rate speed. IDT based the processor cores on the 32-bit MIPS ISA (instruction-set architecture). Interprise processors target SOHO (small-office/home-office) routers, Ethernet switches, WAPs (wireless-access points), and VPN (virtual-private-network) equipment.

INTEL

Intel's (www.intel.com) Atom, the company's smallest and lowest-power processor, targets small devices and low power and maintains the Intel Core 2 Duo instruction set. Intel's N270 processor and 945GSE Express chip set target the low-power needs of embedded-system markets, such as digital signage, interactive clients, thin clients, digital security, residential gateways, print imaging, and industrial control.

KAWASAKI MICROELECTRONICS

K-Micro's (Kawasaki Microelectronics', www.k-micro.us) processors target the consumer-electronics, computer, office-automation, networking, and storage markets. K-Micro's computing subsystem includes a MIPS32 24Kf processor, the Sonics Silicon-Backplane and Sonics3220 Smart interconnects, the SafeNet SafeXcel security engine, and an off-chip OCP (Open Core Protocol) interface.

LATTICE SEMICONDUCTOR

Lattice Semiconductor's (www.latticesemi.com) open-source LatticeMico32 soft microprocessor core combines a full 32-bit-wide instruction set with 32 general-purpose registers. Designers can customize the microprocessor core. The Wishbone buses provide a standard mechanism for connecting the microprocessor to a variety of peripherals and memory controllers. Lattice also provides the open-source, 8-bit LatticeMico8, 8051, 68xx series, PIC, and 6502 microcontrollers through its partners.

MARVELL TECHNOLOGY GROUP

Marvell Technology Group (www.marvell.com), a fabless semiconductor company, ships more than 1billion chips a year. Marvell's microprocessor and DSP architectures target high-volume storage, mobile and wireless, networking, consumer, and "green" products.

MAXIM INTEGRATED PRODUCTS

Maxim Integrated Products (www.maxim-ic.com) offers 8-, 16-, and 32-bit microcontrollers for embedded-system applications. In the last two years, Maxim has acquired Innova Card, Teridian Semiconductor, and the Zatara and Crimzon product lines from Zilog. Evaluation kits, application notes, reference designs, and technical documents are available to support customers through the development process.

MICROCHIP TECHNOLOGY

Microchip (www.microchip.com) this year expanded its eXtreme Low Power portfolio of 8- and 16-bit PIC microcontrollers with several new families, including devices featuring 50 µA/MHz active current consumption and sleep currents as low as 20 nA. The mTouch sensing portfolio includes a royalty-free technology for projected capacitive touch sensing. The company added agency-certified Wi-Fi modules and low-power, less-than-1-GHz radios and modules to its wireless portfolio. Microchip acquired SST's (Silicon Storage Technology's) FlashFlex 8051 microcontrollers.

MIPS TECHNOLOGIES

MIPS Technologies (www.mips.com) provides MIPS-based IP (intellectual-property) cores. In the past year, the company introduced the M14K and M14Kc cores for microcontrollers and real-time-embedded-system applications, announcing its entry into the mobile-handset market. Licensees are creating products with Android beyond mobile handsets. MIPS provides optimizations for Adobe Flash Player, Skype, Yahoo! TV Widgets, and other key platforms for connected products.

NETHRA

Nethra Imaging (www.nethra.us.com), a fabless semiconductor company, focuses on image-, video-, and signal-processing applications, including video, medical, and military markets. In addition to the Am2045 massively parallel processor, Nethra also provides image-processor chips, integrated with leading CMOS image-sensor devices, for consumer, surveillance, and professional cameras.

NETRONOME

Netronome (www.netronome.com) develops programmable products for intelligent flow processing in network and communications devices. The company's products include NFPs (network-flow processors) and acceleration cards that scale to 100 Gbps. The NFP and acceleration-card family targets carrier-grade and enterprise-class communications products that require deep-packet inspection, flow analysis, content processing, virtualization, and security.

NXP

NXP's (www.nxp.com) ARM portfolio comprises Cortex, ARM7-, ARM9-, and 80C5-based microcontrollers. The ARM Cortex-M0-based devices include the lowest-priced, 32-bit microcontroller. The ARM Cortex-M3-based microcontroller devices feature a high level of integration and low power consumption. This year, NXP acquired Jennic's portfolio of 802.15.4 and Zig-

bee low-power RF products.

OKI SEMICONDUCTOR

Oki Semiconductor's (www2.okisemi.com) Advantage microcontroller family comprises ARM-core-based products ranging from the ML671000 with a built-in USB (Universal Serial Bus) controller to the high-performance, 120-MHz, ARM946E-based 6200 series with instruction and data caches.

PMC-SIERRA

PMC-Sierra's (www.pmc-sierra.com) MIPS-based processors target metropolitan-transportation, storage-area-networking, wireless-equipment, VOIP (voice-over-Internet Protocol), Internet-routing-equipment, enterprise-switch, and multifunction- and laser-printer applications. The MSP (multiservice-processor) family targets use in CPE (customer-premises equipment), such as wired and wireless VOIP-terminal adapters, home gateways, voice-enabled routers, and NAS (network-attached storage).

RABBIT SEMICONDUCTOR

Rabbit Semiconductor (www.rabbit.com), a Digi International company, provides high-performance, 8-bit microprocessors and development tools for embedded control, communications, and Ethernet connectivity. Rabbit offers embedded-design systems, including low-cost development kits, and technical support for both hardware and software.

RAMTRON

Ramtron's (www.ramtron.com) FRAM (ferroelectric-random-access-memory)-enhanced Versa 8051 microcontrollers combine a high-performance SOC (system on chip) with nonvolatile FRAM. FRAM writes at bus speed with virtually unlimited endurance and low power for guaranteed data integrity in systems that require rapid and frequent writes and low power consumption.

RENESAS ELECTRONICS AMERICA

Renesas Electronics America (am.renesas.com) is the result of a merger between Renesas Technology and NEC Electronics. Processor offerings extend from low-power, 8- and 16-bit microcontrollers to high-performance, 32-bit microprocessors. The R8C/Tiny targets electronic ballasts, handheld power tools, and motor-control systems. R8C/3x devices target automotive-body-control applications. The H8S/2153 targets advanced communication equipment, and the H8SX/2164 targets baseboard-management-controller applications. The 32-bit V850 series microcontrollers feature low-voltage operation and DSP functions.

SAMSUNG ELECTRONICS

Samsung (www.samsung.com) offers 16- to 32-bit processors targeting handheld-system applications, including smartphones, VOIP (voice-over-Internet Protocol) phones, portable GPS (global-positioning-system) devices, gaming systems, and PDAs (personal digital assistants). Samsung's family of mobile application processors features ARM-based RISC cores.

SEMTECH

Semtech (www.semtech.com) offers 8- to 22-bit microcontrollers that interface sensors and radio transceivers and target autonomous, battery-operated, wireless devices. The Radio Machine device for ISM (industrial/scientific/medical)-band-transceiver interfacing includes a low-power RISC core with the BitJockey, a serial interface for radio protocols, and a UART. The Sensing Machine device for sensor interfacing includes a low-power RISC core with the high-resolution ZoomingADC sigma-delta ADC and a programmable preamplifier.

SILICON LABORATORIES

Silicon Laboratories (www.silabs.com) offers 8-bit, mixed-signal microcontrollers that combine high-performance, 8051-compatible cores with precision analog peripherals in tiny-footprint packages. This year, the company expanded its F9xx family to include devices that deliver lower power consumption in active mode, sleep mode, and deep-sleep mode as low as 10 nA without the real-time clock operating and with full RAM retention. Silicon Labs also introduced the F8xx and F99x families of capacitive touch-sense microcontrollers.

SILICON STORAGE TECHNOLOGY

SST (Silicon Storage Technology, www.sst.com), now a wholly owned subsidiary of Microchip Technology, offers microcontrollers that implement the 8051 instruction set and are pin-for-pin-compatible with standard 8051 devices. FlashFlex microcontrollers are available in single- or dual-block configurations, and they are ISP (in-system-programmable) and IAP (in-application-programmable). These microcontrollers target consumer, communication/wired, imaging and video, audio, industrial, and motor-control applications.

STMICROELECTRONICS

STMicroelectronics (www.st.com) offers a portfolio of 8-bit microcontrollers, 32-bit ARM-based microcontrollers, and 32-bit ARM-based embedded microprocessors. STMicro's 8-bit microcontrollers feature an advanced STM8 8-bit core for industrial and appliance applications. The STM32 are Cortex-M cores in more than 130 fully compatible devices. ARM926 cores power the 32-bit, embedded Spear microprocessors, which are available in single- and dual-core families.

STRETCH

Stretch (www.stretch-inc.com), a fabless semiconductor company, provides software-configurable processors. Design engineers can configure Stretch's off-the-shelf processors by using standard C/C++-programming methods and Stretch software-development tools. The Stretch S6 SCP (software-configurable-processor) engine powers the Stretch S6000 family of SCPs, which incorporate the Tensilica Xtensa LX VLIW (very-long-instruction-word) processor core, a second-generation ISEF (instruction-set-extension fabric), and a tightly coupled programmable accelerator.

SYNOPSYS

Synopsys' (www.synopsys.com) DesignWare ARC processors include the 32-bit DesignWare ARC 600 and 700 families of configurable RISC/DSP cores, configurable extensions and software, and development tools. All DesignWare ARC cores use a 16/32-bit ISA (instruction-set architecture) that provides both RISC and full DSP capabilities. The DesignWare ARC cores are synthesizable. The DesignWare ARC Sound and ARC Video subsystems combine with optimized codecs and Synopsys' Sonic Focus audio-enrichment software to target audio and video products.

SYSTEMYDE INTERNATIONAL

Systemyde International (www.systemyde.com) provides microprocessor IP (intellectual property), with emphasis on Z80-, Z180-, and Z8000-compatible architectures. As the original designer of all five generations of Rabbit microprocessors, Systemyde also provides these designs in IP form. Systemyde IP comes in Verilog HDL that can target either ASIC or FPGA implementations.

TENSILICA

Tensilica (www.tensilica.com) offers 32-bit, customizable data-plane processors, DSPs, and standard processor cores. All of Tensilica's processor cores come with software-tool chains that automatically match any changes the designer makes. Xtensa 8 has all the basic configurable capabilities, and Xtensa LX3 offers designers opportunities to bypass the system bus with direct FIFO (first-in/first-out) and GPIO (general-purpose-input/output) capabilities. This year, Tensilica introduced its second-generation ConnX Baseband Engine DSP for LTE (long-term-evolution) handsets and base stations. Tensilica also introduced its third-generation Diamond Standard controller cores and its HiFi EP DSP core.

TEXAS INSTRUMENTS

Texas Instruments' (www.ti.com) microcontroller portfolio includes ultralow-power, 16-bit MSP430, Stellaris 32-bit ARM Cortex-M3, and real-time-control TMS320C2000 microcontrollers. More than 500 devices provide a broad range of price, performance, and peripherals to target medical, industrial, renewable-energy, metering, motor-control, automotive, and other applications. TI introduced the MSP430 Value Line microcontroller family. Its microprocessor portfolio includes the high-performance Sitara ARM Cortex-A8 and ARM9 microprocessors targeting industrial, medical, and consumer applications.

TIEMPO

Tiempo (www.tiempo-ic.com) offers technology for use in semiconductors requiring low power, highly secure operating characteristics, or both. Its patented clockless, delay-insensitive approach to chip design is available as IP (intellectual-property) cores that designers can implement using standard EDA tools and formats.

TILERA

Tilera (www.tilera.com) offers high-performance multicore processors targeting embedded networking, security, and multimedia-processing applications. The Tile processor family targets applications requiring intensive packet processing for layers 2 through 7 and for HD (high-definition)-video applications. The Tile64 processor SOC (system on chip) has 64 full-featured processor cores plus a rich suite of system-integration blocks.

TOSHIBA AMERICA ELECTRONIC COMPONENTS

Toshiba (www.toshiba.com) offers 32-bit ARM processors and 8/16/32-bit CISC microcontrollers that target cell phones, MP3 players, cameras, medical devices, and automotive electronics. Toshiba offers highly integrated 8-, 16-, and 32-bit CISC microcontrollers with embedded SuperFlash memory and 32- and 64-bit, MIPS-based TX RISC microprocessors. TX RISC microcontrollers suit calculation-intensive applications that require large memory capacity and DSP-like functions, such as consumer digital-camera lenses, digital cam-

corders, and automotive-air-bag systems.

UBICOM

Ubicom (www.ubicom.com) develops communications and media processors and software platforms that target real-time interactive applications and multimedia-content delivery in homes. The company provides to OEMs optimized system-level products, including wireless routers, access points, bridges, VOIP (voice-over-Internet Protocol) gateways, connected digital-photo frames, streaming-media devices, and other network devices.

VIA TECHNOLOGIES

Via Technologies (www.via.com.tw), a fabless supplier of power-efficient x86 processor platforms, targets the PC, client, ultramobile-system, and embedded-system markets. The company supports a spectrum of computing and communication platforms, including its ultracompact main boards.

WESTERN DESIGN CENTER

Western Design Center (www.westerndesigncenter.com) licenses its 65xx brand microprocessor IP (intellectual property). The company's product line includes the 8-bit W65C02SRTL and 8/16-bit W65C816SRTL licensable IP. In addition to IP, Western Design Center offers 8- and 8/16-bit processor devices.

XILINX

Xilinx (www.xilinx.com) provides programmable-logic products, including embedded processors, FPGA platforms, and development tools that target aerospace, defense, wired- and wireless-communications, automotive, audio- and video-broadcast, industrial-control, test-and-measurement, and consumer applications. Virtex FPGAs include the 32-bit, hard-core PowerPC. The configurable, 32-bit MicroBlaze soft core is available for use with Spartan and Virtex FPGAs.

XMOS

XMOS (www.xmos.com) provides a software-defined silicon, programmable chip based on an array of high-performance, event-driven processors. You create designs in high-level languages, delivering hardware performance from a software-based design flow. XMOS devices blend a high-performance processor architecture with a responsive I/O structure to provide designers with custom silicon.

ZILOG

Ixys last year acquired Zilog (www.zilog.com). The company offers the 8-bit Z8, Z8 Encore!, and Z80 Acclaim microcontroller families targeting the industrial and consumer markets. Zilog offers single-board computers and application-specific software stacks targeting energy-management, monitoring, metering, and motion-detection applications. EDN

BY MIGUEL RODRIGUEZ, PLX TECHNOLOGY • LEE MOHRMANN, NATIONAL INSTRUMENTS

Spread-spectrum clocking reduces EMI in embedded systems

PCI EXPRESS TECHNOLOGY INCORPORATES THE USE OF SPREAD-SPECTRUM CLOCKING TO REDUCE EMI.

For years now, government institutions have been regulating the amount of EMI (electromagnetic interference) an electronic device or system can emit. Their efforts primarily target lowering dissipated power and eliminating any interference to the function of other surrounding devices as a result of EMI. Spread-spectrum clocking is a popular implementation for reducing EMI in synchronous systems.

SPREAD-SPECTRUM-CLOCKING BENEFITS

EMI is the energy resulting from a periodic source in which most of the energy becomes a single fundamental frequency. The influence of these unwanted signals can manifest itself in the limited operation of other devices and systems. In some cases, the EMI-generated disturbance can make it impossible for these devices or systems to operate. Because an electromagnetic signal must have a source, synchronous systems are ideal candidates for generating excessive EMI. Within a system, the coupling paths in PCBs (printed-circuit boards) transmit the generated EMI that affects other system components. However, EMI can occur even in the absence of a conductive medium, such as an electric conductor or dielectric. In most cases, EMI results from a combination of conduction and radiation.

The primary PCIe (PCI Express) model implements a synchronous-clocking scheme. That is, the same 100-MHz clock source generates the reference clock for PCIe devices. Furthermore, in the case of a motherboard, the traces on the PCB can act as coupling paths to facilitate the transmission of EMI to the surrounding devices. The disturbance that occurs can affect not only the system but also other surrounding systems when EMI travels through the atmosphere in the form of radiation.

One method of minimizing the EMI that a device generates is to keep the disturbing signals below a certain level. You accomplish this goal by modulating the disturbing signals across a wider frequency range, thus spreading the energy across a range of frequencies rather than concentrating it at one frequency. In PCIe systems, the modulation of the reference clock is spread-spectrum clocking.

The most common modulation techniques are center-spread and down-spread. The center-spread approach applies the modulated signal in such a way that the nominal frequency sits in the center of the modulated frequency range. That is, half of the modulated signals deviate above the nominal frequency, and the other half deviate below it. A down-spread approach also results in a range of deviated frequencies. However, in the down-spread approach, the modulated signals deviate below the nominal frequency.

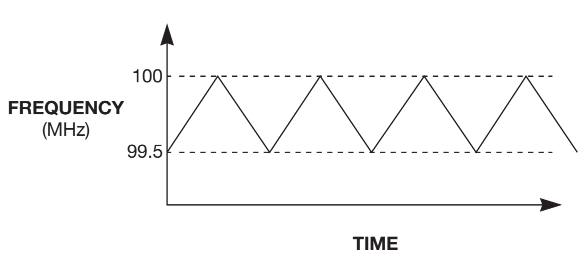

Figure 1 The PCIe specification uses the down-spread approach when using a 30- to 33-kHz-wave signal as the modulating frequency to the 100-MHz clock, resulting in a frequency range of 99.5 to 100 MHz.

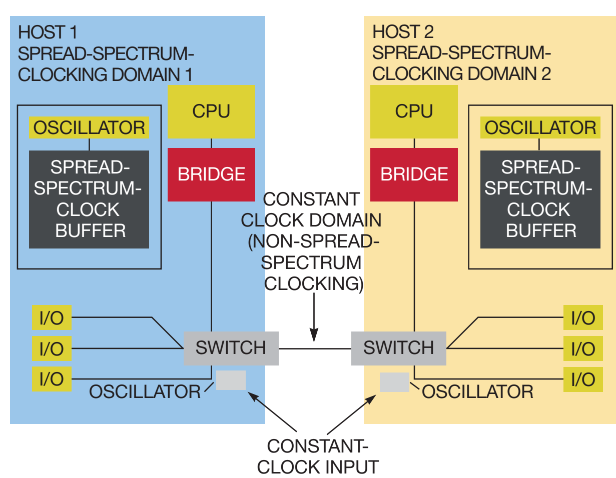

Figure 2 PCIe switches provide an isolation feature that helps eliminate communication issues between two systems when one or both of those systems uses spread-spectrum clocking (courtesy PLX Technology).

Many PCIe systems implement EMI-minimizing spread-spectrum clocking by spreading the spectral energy of the clock signal over a wide frequency band. In spread-spectrum-clocking systems, PCIe components generally must use a reference clock from the same source. This approach allows a transmitter PLL (phase-locked-loop) and a receiver-clock-recovery function, or clock-data-recovery circuit, to track the modulation frequency and remain synchronous with each other. If only one side of the link uses a spread-spectrum-clocking reference clock, the transmitter and receiver circuits cannot properly track one another. For example, if a PCIe add-in card interfaces to a spread-spectrum-clocking system and also implements a cable connection to a downstream card that is using a constant-frequency-clock source, the downstream interface will be unable to connect.

The PCIe base specification provides guidelines for modulating the reference-clock input to PCIe devices. At a high level, the PCIe specification uses the down-spread approach when using a 30- to 33-kHz-wave signal as the modulating frequency to the 100-MHz clock, resulting in a frequency range of 99.5 to 100 MHz (**Figure 1**).


Figure 3 This PXIe-1082 chassis has four hybrid slots, three PXIe slots, and one PXIe system-timing slot (courtesy National Instruments).

ISOLATION IN PCIe SWITCHES

To solve a link-up problem due to mixing spread-spectrum- and constant-frequency-clocking implementations, designers must provide a means to pass the spread-spectrum clock to all of the devices. This task poses a challenge in modular systems at both the physical and the electrical levels. A better option would be to use the spread-spectrum-clocking isolation function available in select PCIe switches (**Figure 2**). These switches provide an isolation feature that helps eliminate the issue of trying to communicate between two systems when one or both of those systems use spread-spectrum clocking.

The switch has the necessary buffering and logic required to allow the upstream port to operate using both a spread-spectrum-clocking and a constant-frequency-clock source. You can use strapping options to enable this feature in the switch. When you enable the switch, its Port 0 operates in the spread-spectrum-clocking domain, and the other ports operate in the constant-frequency-clock domain. The ability of the switch to function in two clock domains provides system designers flexibility in expanding modular systems using cable, as well as simplifying the overall system-clocking scheme.

The separation of clock domains delivers numerous benefits, including the reduction of phase jitter and the ability to link systems with independent clocking sources. With this ability, the use of a nontransparent bridge becomes more flexible. Because of the clocking requirements of PCIe, few system architectures can take advantage of nontransparent bridges. Their primary use has been in embedded systems using the second root-complex subsystem in a fault-tolerant or fail-over application or in RAID (redundant-array-of-inexpensive-disk) controllers. In both cases, the secondary system still connects to the primary in clocking architecture; therefore, the approach has limited flexibility because all system components using PCIe must use the same clocking source.

With the ability to separate clock domains, independent systems can link because the secondary clock domain is independent of the primary domain. With this capability and the use of nontransparent bridges, two or more PCs can connect over PCIe, and most of the systems can operate in a reduced-emissions mode. Using low-cost PCIe hardware, a new high-speed, low-latency interface creates a powerful computing environment.

One application of this environment may be a switch module in a blade-server chassis (**Figure 3**). With the constant-frequency clock on the module side and each blade using off-the-shelf components, the blade system becomes a

low-cost supercomputer without the latency and bandwidth limitations of Ethernet or the cost and complexity issues of InfiniBand. The use of the isolated-clock domains enables new application for systems using standardized components. The new PXI (PCI extensions for instrumentation) multicomputing specification employs this technology.

The other benefit of using independent clock domains is to reduce phase jitter. For PCIe systems, phase jitter is the accumulation of nonideal frequency components in the reference clock that spread to PCIe devices. General-purpose computing platforms typically employ cost-effective clocking architectures. For systems that provide expansion capabilities, such as cabled expansion chassis, the phase jitter is a key parameter for interoperability.

THE ABILITY OF THE SWITCH TO FUNCTION IN TWO CLOCK DOMAINS PROVIDES FLEXIBILITY IN EXPANDING MODULAR SYSTEMS USING CABLE AND SIMPLIFIES THE OVERALL CLOCKING SCHEME.

This fact is important because the energy in the nonideal frequencies of the clock adds up to the time-domain jitter profile. Certain frequencies contribute to the jitter in the link budget. As distance between the devices increases, the time-domain jitter changes behavior and usually increases. The common implementations for PCIe provide a 12-nsec delay for phase-jitter analysis. In cabled interfaces, this delay ranges from 10 to 70 nsec. In addition, buffering the reference clock adds jitter to the signal. This unpredictable behavior of the reference clock requires an approach that provides a degree of certainty for the link budget. Isolating the expansion reference clock from the system's cost-effective clocking circuits greatly reduces interoperability issues. As the interest in general-purpose graphics processors enhances the computational capabilities of a single system, expansion systems' additive jitter will become an issue that clock-domain isolation can address. EDN

AUTHORS' BIOGRAPHIES

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EDITED BY MARTIN ROWE
AND FRAN GRANVILLE

designideas

READERS SOLVE DESIGN PROBLEMS

Ceramic speaker driver also drives motors

John Guy, National Semiconductor Corp, Santa Clara, CA

National Semiconductor's (www.national.com) LM48556 ceramic speaker driver drives speaker elements with peak-to-peak voltages as high as 14V. However, the device also works in other applications. This Design Idea shows how to use the speaker driver to drive an ERM (eccentric-rotating-mass) vibration motor. In this application, the speaker driver delivers as much as 5V into a typical ERM motor, decreasing its start-up time by approximately 50%.

The LM48556 has balanced differential inputs with an internal bias voltage.

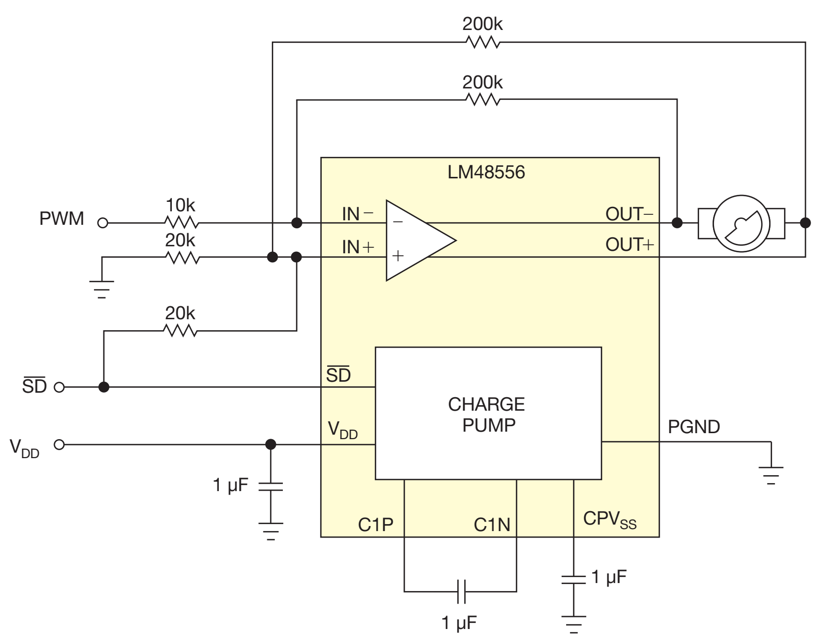

Figure 1 The LM48556 can operate dc-coupled to drive a motor; it needs ac-coupling capacitors to drive a speaker.

TABLE 1 BILL OF MATERIALS

Quantity	Description	Dimensions (L×W×H, mm)	Part
One	Driver	2×1.5×0.65	LM48556
Three	1-µF capacitor	1×0.5×0.5	6V X5R
Seven	Miscellaneous resistors and capacitors	0.6×0.3×0.3	Noncritical

Although it functions with ac-coupling capacitors in series with the input resistors and across the feedback resistors, it also functions as a dc-coupled device without the capacitors. **Figure 1** shows the external components you need to drive an EMR motor with the IC.

Note that the shutdown $\overline{SD}$ signal's high voltage must be the same as the PWM (pulse-width-modulation) high level to get a differential zero output at 50% duty cycle. Testing found this circuit operational with logic voltages of 1.2 to 3.4V, but the speaker driver has a guaranteed logic high of 1.2V or higher. If the PWM source has a logic voltage of less than 1.2V, you must drive the $\overline{SD}$ pin with a separate higher logic voltage.

When you use this device with 1-µF capacitors, it can deliver 5V into 30Ω at voltages as low as 3.2V. Replacing these capacitors with a 4.7-µF "flying" capacitor and a 10-µF reservoir capacitor allows the LM48556 to drive 5V into 30Ω at voltages as low as 3V. **Table 1** lists the parts you need. EDN

DIs Inside

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Light collar helps you find your pet in the dark

Vladimir Oleynik, Moscow, Russia

If you have a pet, you know how difficult is to find him or her in the dark, especially when your pet has dark fur. The circuit in **Figure 1** lets you build a collar with LEDs that helps you find your pet.

The heart of the circuit is the ZXLD381FHTA LED driver from Zetex (www.diodes.com). Two 1.2 or 1.5V cells power the LED driver, providing the current pulses to illuminate six to eight 20-mA LEDs of any color series. The ZXLD381 dc/dc boost converter's primary application is in LED drivers. A 10-µH inductor helps maintain output voltage higher than the input voltage. Zetex's ZXLD381 data sheet contains hints on inductor selection (**Reference 1**).

The circuit contains a light sensor and the LED driver. The LED driver's operation starts when the ambient-light level drops below a certain threshold. When the light level is high, the low collector-to-emitter resistance of the L-7113P3C phototransistor from Kingbright (www.kingbright.com) keeps transistors Q_1 and Q_2 off, and the LEDs don't light. When it gets dark and the voltage at Point A goes high enough, Q_1 and Q_2 turn on and saturate, providing power for the LED driver.

To power the light collar, you can use any cell or battery with voltage of 1.2 to 10V. Zetex's ZXLD381FHTA operates at 0.9 to 10V at its common-cathode-voltage pin, V_{CC}, but the light sensor's voltage drop slightly narrows it. The LEDs' efficiency decreases when the power supply is at its low limit. If you don't need the light sensor, then omit all resistors, the phototransistor, and both transistors. Meanwhile, the light sensor lengthens battery life, especially if you expect to use the collar frequently. If you use the collar, you can discharge the battery to a voltage lower than 1.2V before discarding it. When the battery voltage drops to 1.2V, connect its battery's positive terminal through switch S_1 directly to the LED driver's V_{CC} pin, which bypasses Q_1's collector-to-emitter junction with jumper J_1. In that case, the light sensor is off, and the minimum power-supply range decreases to 0.9V.

The ZXLD381FHTA comes in a space-saving SOT-23 package. The other circuit components are available in either surface-mount or through-hole versions. The surface-mount versions for Q_1 and Q_2 are the BC857C and the BC847C, respectively, and the through-hole versions are the BC557C and the BC547C, respectively. The circuit's size does not exceed 0.5 in.^{2} (12.7×25.4 mm) when you use SMD components and 1 in.^{2} (25.4×25.4 mm) when you use through-hole-type components.

TO IMPROVE DETECTION OF YOUR PET, YOU SHOULD PLACE ALL LEDs EVENLY ALONG THE COLLAR'S PERIMETER.

The phototransistor in a through-hole package is easier to see under your pet's fur. Also, it's more convenient to use LEDs with wider viewing angles and larger diameters.

Powering the collar with two fresh AA 1.5V cells in a well-illuminated environment in standby mode consumes approximately 25 µA. In a dark environment, the average consumption is about 7 mA. Four Kingbright L-53SRD-H LEDs illuminate the collar.

To improve detection of your pet, you should place all LEDs evenly along the collar's perimeter. You may also need to prevent the pet's fur from overshadowing the phototransistor and LEDs. Your pet may need some time to get used to its new lighting collar. The collar bends in different directions during use, so make it flexible or arrange it as several rigid PCBs (printed-circuit boards) with a wired connection.EDN

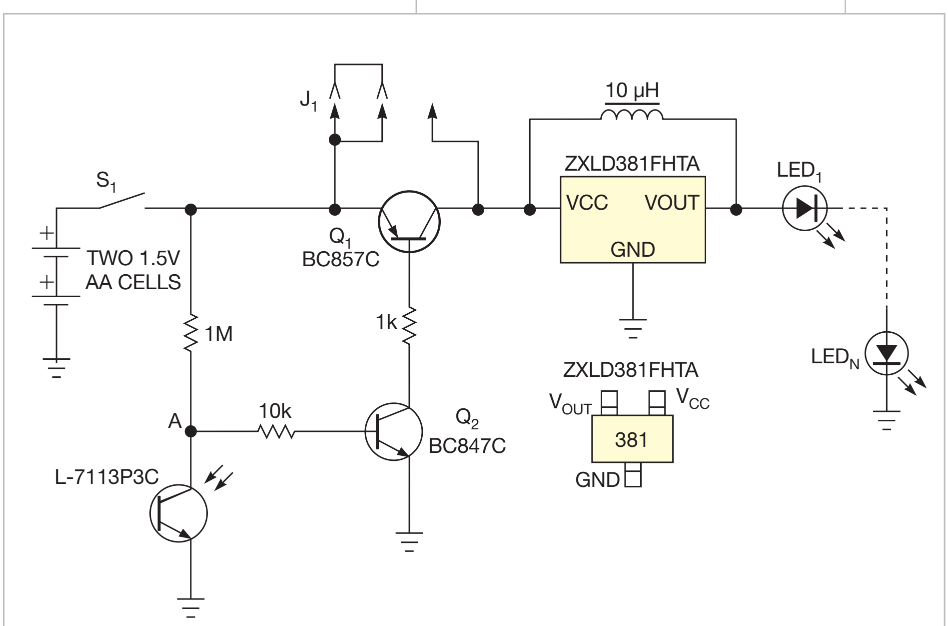

Figure 1 This circuit lets you build your pet a lighted collar.

REFERENCE

1 "ZXLD381, Single or multi cell LED driver solution," Diodes Inc, May 2010, www.diodes.com/datasheets/ZXLD381.pdf.

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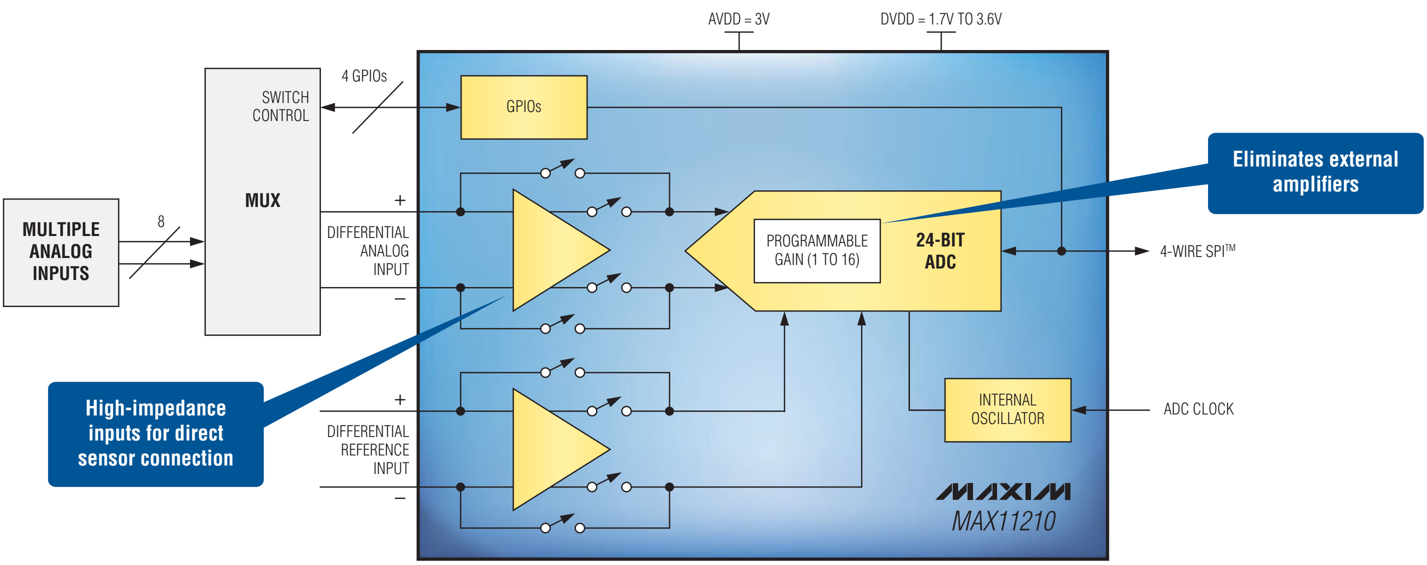

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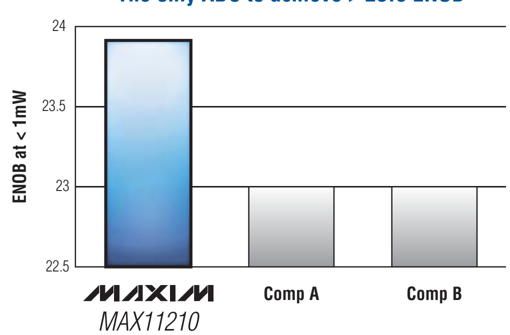

Resolution (Bits)	4-Wire SPI Programmable Gain	4-Wire SPI Unity Gain	2-Wire Serial
24	MAX11210	MAX11200	MAX11201, MAX11202
20	MAX11206*	MAX11207*	MAX11208
18	MAX11209*	MAX11211*	MAX11212
16	MAX11213	MAX11203	MAX11205

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Accurately simulate an LED

Jon Roman and Donald Schelle,
National Semiconductor Corp, Santa Clara, CA

Solid-state-lighting applications are quickly moving into the mainstream. Although they are more efficient, the LEDs that produce the low-cost light often require a complicated driver circuit.

Testing the driver circuit using LEDs, although easy, yields only typical results because the tests don't factor in worst-case LED parameters and often generate undesirable light and heat during driver debugging. Although using a constant resistance might seem to be an appropriate approach, a resistor approximates an LED load at only one point on the current/voltage curve. An electronic load may prove to be a more useful approach. The control loops of the driver circuit and the electronic load, however, often result in system instability and oscillations.

Figure 1 illustrates a typical LED-driver circuit using a low-cost simulated-LED circuit. The simulated LED accurately mimics a real LED at a user-programmable threshold voltage. A simple Darlington current sink, Q_1, provides a wide range of LED threshold voltages. The size of the heat sink attached to Q_1 and the power capability of Q_1 are the only limits on the amount of power the simulated LED can dissipate.

THE SOFT TURN-ON OF THE SIMULATED LED ACCURATELY MIMICS THAT OF A REAL LED.

You can easily tune the circuit for any LED voltage. Place a constant voltage across the simulated LED. Tune the circuit by adjusting resistor R_1 until the circuit draws the desired current. You can adjust the shape of the voltage knee by making small changes to resistor R_3, although this step is not usually necessary.

Figure 2 compares the simulated LED's current and voltage characteristics to those of a real LED and a constant resistance. The soft turn-on of the simulated LED accurately mimics that of a real LED. Furthermore, the simulated LED quickly retunes to test minimum and maximum LED characteristics, thus giving you confidence that the circuit will work over all load conditions. EDN

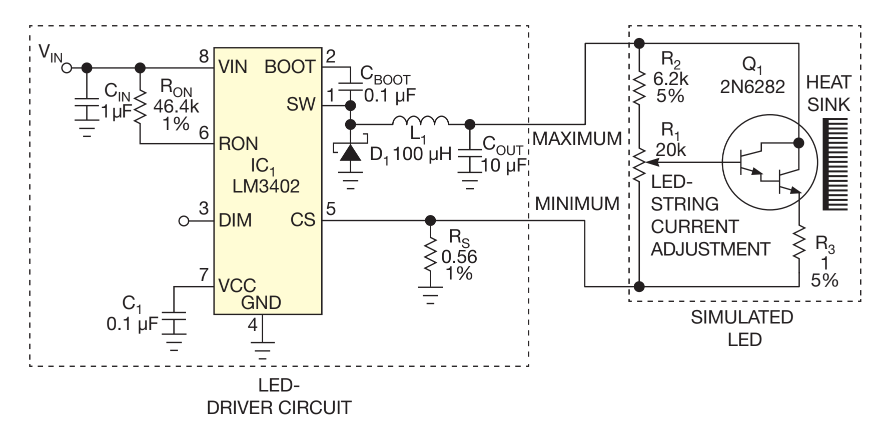

Figure 1 Use this circuit for quick testing of an LED-driver circuit over minimum, typical, and maximum LED parameters.

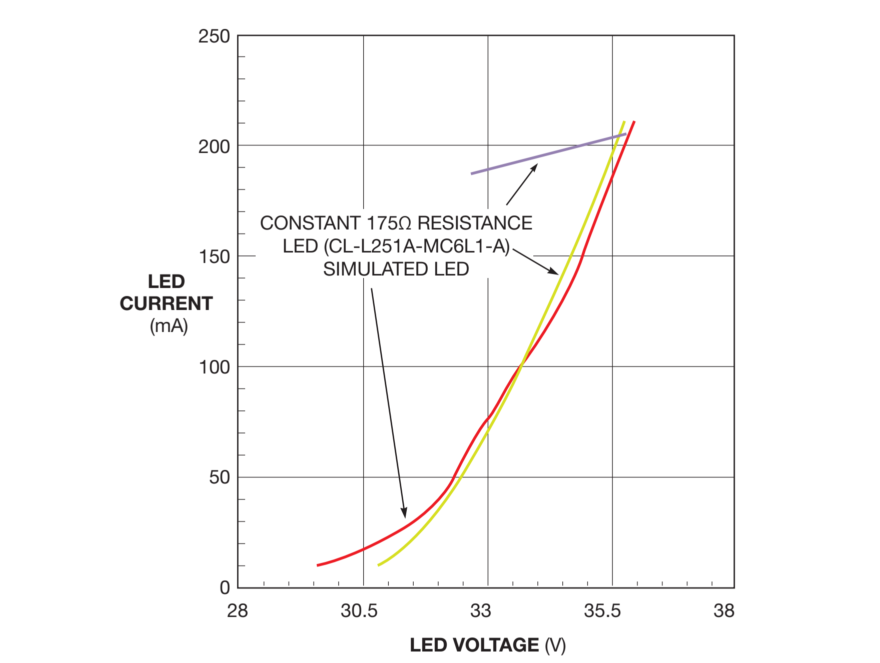

Figure 2 The simulated LED approximates the turn-on characteristics of a real LED. A constant-resistance load approximates a real LED load at only one point on the curve.

Perform hexadecimal-to-BCD conversion in firmware

Abel Raynus, Armatron International, Malden, MA

Microcontroller firmware usually deals with hexadecimal code. You sometimes need to display the content of registers, which requires a hexadecimal-to-BCD (binary-coded-decimal)-code conversion. The programming technique for this conversion is an add-three algorithm. Fortunately, you can adapt this technique for use with an 8-bit microcontroller assembler. You can, however, easily adapt this approach to any assemblers because the approach uses a set of standard instructions.

The number of BCD registers this program requires depends on the number of bits of the hexadecimal digits necessary to contain the maximum value of equivalent BCD code. The most frequent situation for 8-bit microcontrollers is an input hexadecimal code that comprises one byte with a value of \$00 to \$ff. Its decimal equivalent, accordingly, has a value of 00 to 255. Hence, it needs three digits to be displayed. Each BCD digit needs 4 bits for presentation. Thus, you should organize three 4-bit groups, or BCD tetrads, in firmware.

EACH BCD DIGIT NEEDS 4 BITS FOR PRESENTATION, SO ORGANIZE THREE 4-BIT GROUPS, OR BCD TETRADS, IN FIRMWARE.

The units and tens tetrads form one 8-bit BCD register, and the hundreds tetrad forms half of the second register. Note that all registers for hexadecimal and BCD digits should reside consecutively in memory for ease in performing the multibyte-shift operation. For this reason, they are called digit for initial hexadecimal code, digit+1 for BCD units and tens, and digit+2 for BCD hundreds (**Figure 1**).

Figure 2 shows the flow chart of the conversion process. You can find the assembly code for the procedure in the online version of this Design Idea at www.edn.com/101007dia. The conversion starts by checking each BCD tetrad to detect whether its value is more than or equal to five. If it happens in any of BCD tetrads, then it adds a three to that tetrad. Next, all the registers—digit, digit+1, and digit+2—shift left starting with the LSB (least-significant-bit) digit. These operations continue until the registers shift N times, where N is the number of bits in the initial hexadecimal code. In this case, N=8. The result of conversion can be read from the registers digit+1 and digit+2. EDN

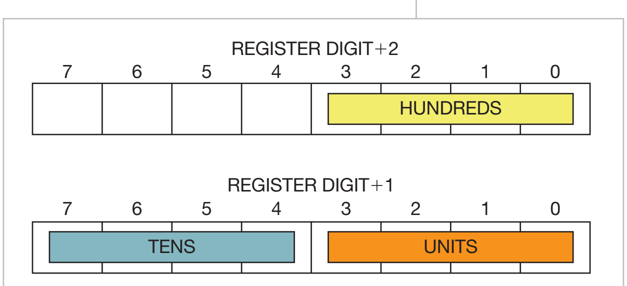

Figure 1 Representing two hex digits (one byte) in BCD format requires three 4-bit tetrads.

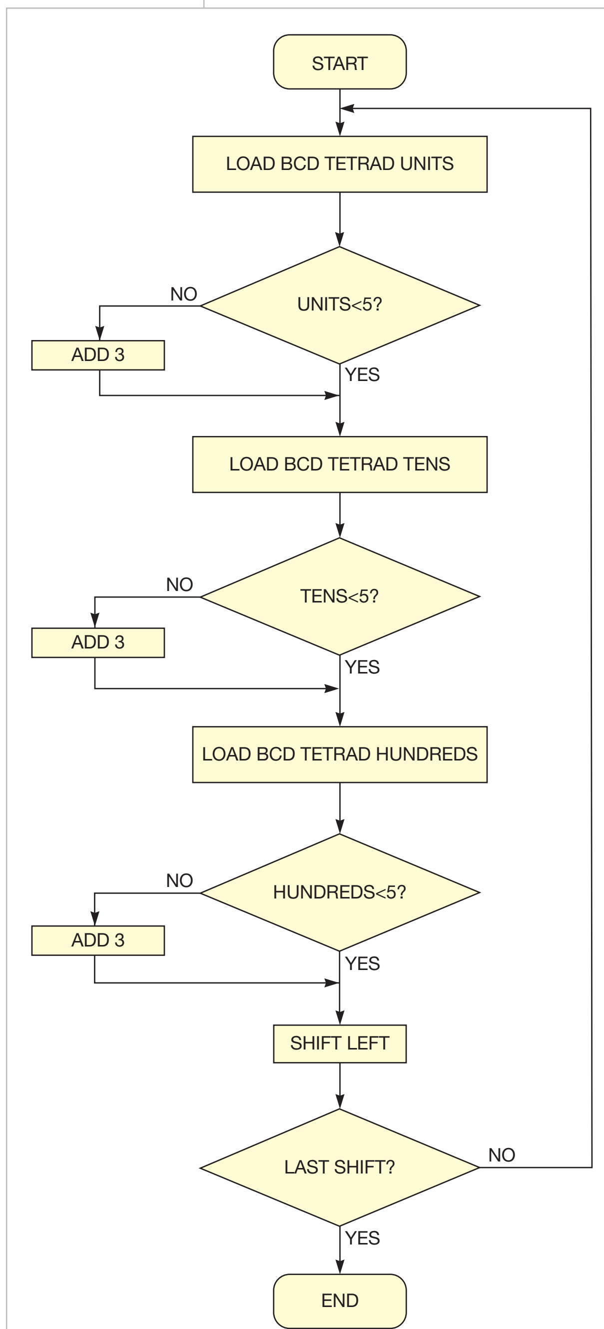

Figure 2 The conversion algorithm checks the units, tens, and hundreds for values less than five and adds three.

LED-LIGHTING TEAR-DOWNS:

lighting designs illuminate the future of lighting

A SPECIAL *EDN* SECTION

BY MARGERY CONNER • TECHNICAL EDITOR

5 LIGHTING DESIGNS illuminate the future of lighting

EARLY SSL PRODUCTS ARE MAKING THEIR WAY ONTO STORE SHELVES AND INTO INVENTORY. THESE PRODUCTS CAN INDICATE WHAT DIRECTION SSL DESIGN WILL TAKE, AT LEAST IN ITS EARLY STAGES.

LED-based lighting is still far from a mainstream technology, and its designs are in flux. Consumers have not signaled the price-to-performance ratio for which they will open their wallets and homes, and businesses are reluctant to spend money in the current economic climate. Nevertheless, early SSL (solid-state-lighting) products are making their way onto store shelves and into inventory. These initial designs can indicate what direction SSL design will take, at least in its early stages.

This article describes the tear-down of five LED-lighting products to see how they perform and what components and design topologies they use. It's OK to design in the abstract or to speculate about the most effective ways to use a brand-new technology. The designers and manufacturers of these products, however, have made many assumptions about component pricing and availability, manufacturing and distribution pricing, features that prospective customers will want, and the prices that the market will bear. This level of uncertainty is common when manufacturers are introducing technologies. Five years from now, you'll know what the market wants and is willing to pay for in efficient lighting, but no one now has a clue, partially because of the existence of so many as-yet-undetermined variables. What will the price of energy do? Will the government set an energy policy and stick with it? Will global-energy needs affect investment in energy-efficient hardware?

Considering all the unknowns that face the introduction of SSL products, it's amazing that companies and investors have the courage to invest. It falls to the engineers' lot to make the best design they can with available components for the price point set by the marketers. It's thus interesting and even exciting to peek inside these products and see the mind of the engineer and the mind of the marketer.

This tour of tear-downs begins with a 48-in. LED T8-sized tube light. You can't call it a "replacement" T8 light because it doesn't go into a fixture for fluorescent tubes. Fluorescent tube lighting requires a fixture with a ballast, the lighting industry's term for a fixture-enclosed power supply for a light source. This arrangement works for technologies in which the light source, on aver-

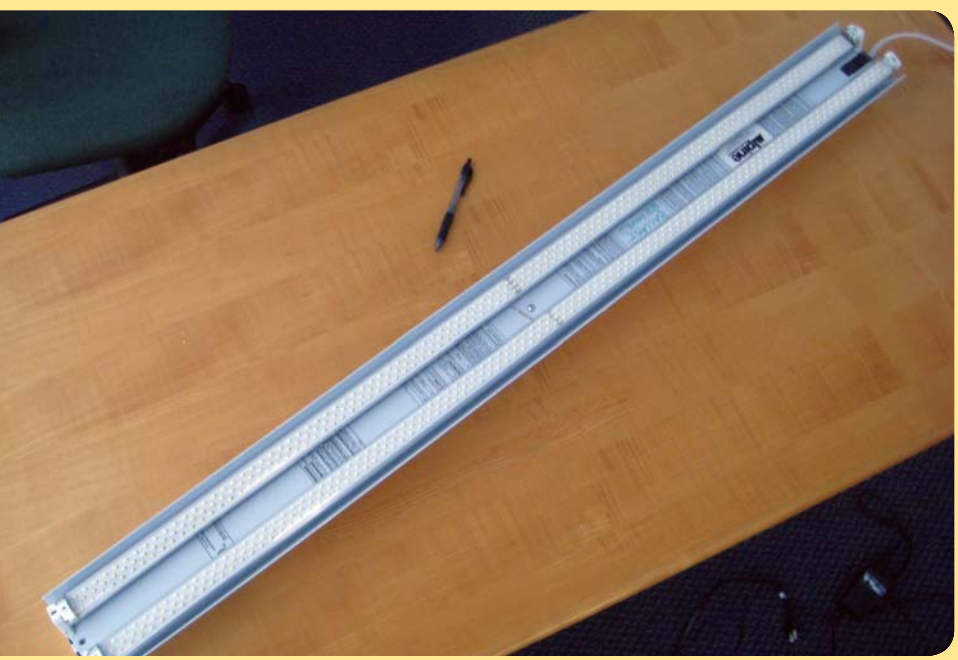

Figure 1 The LED T8 tube light from Alpine Electronics uses a fixture with no ballast and has its own ac/dc power supply.

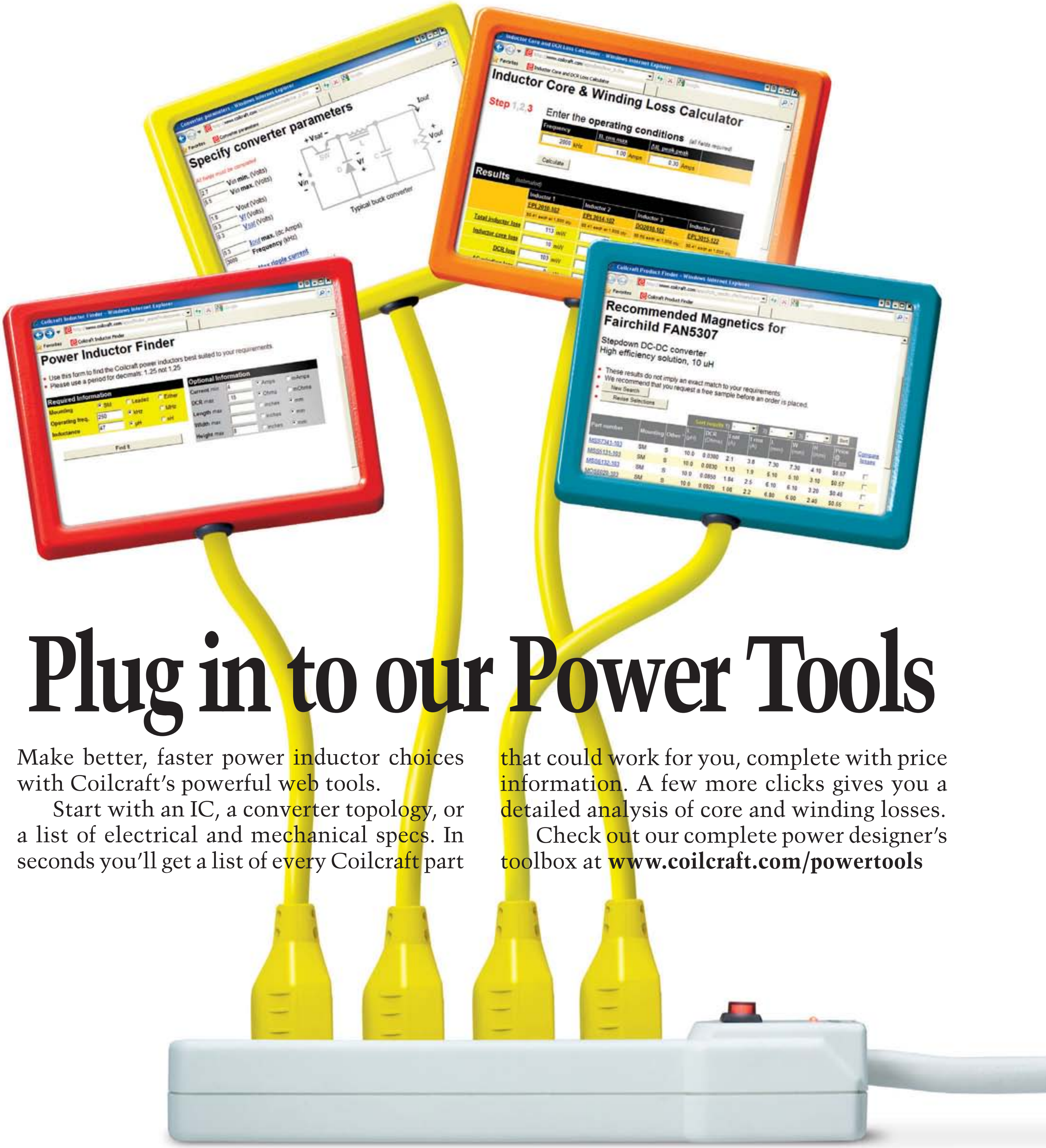

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Figure 2 The T8 comprises three 96-LED rows.

age, wears out before the power-control circuitry. Fluorescent-lighting fixtures apply a voltage to a glass tube containing vaporized mercury. The excited mercury emits photons in the ultraviolet wavelength; these photons strike the phosphor coating on the inside of the tube, in turn emitting light in the visible wavelength. High-quality T8 fluorescent lights have efficacies of 100 lumens per watt and greater.

It is impractical to directly replace a fluorescent tube with an LED tube because the two lights have different power requirements. Most currently available LED tube lights contain their own ac/dc power supplies. In contrast, fluorescent-light fixtures contain the power-converting ballast.

Figure 1 shows an LED T8 tube light from Alpine Electronics. Alpine also provided a modified fluorescent-light fixture with no ballast. Each 18W tube emits 820 lumens, which works out to almost 46 lumens per watt, or just about half of what a high-quality fluorescent tube light emits. **Figure 2** shows that each tube contains three rows of 96 LEDs. When the tube lights, the center row of LEDs are a warmer, yellowish white (**Figure 3**). The end cap routes ac power down to the tubes' internal power supply (**Figure 4**). The aluminum back is a thin, rounded cover that touches the LED PCB (printed-circuit board) only at the edges and doesn't provide much heat sinking. The PCB has no metal core; it looks like a garden-variety fiberglass board. The board itself is thus not a heat sink.

Figure 5 shows the power supply. The part number on the three-terminal power regulator is missing, so it yields no part information. However, the part includes a lot of electrolytic capacitors (**Figure 6**). Two stapled-together PCBs make up the 4-foot-long light. **Figure 7** shows the staples that connect the two boards, and **Figure 8** shows the top view of the staples and the jumpers that route the power bus.

The specs for the light claim that the tube has a 50,000-hour lifetime; with all those electrolytic capacitors, though, this figure seems dubious. It's possible to get a 50,000-hour lifetime with electrolytic capacitors, but I think the manufacturer may have just picked the general-lifetime number for LED components and used that figure for the whole light. The tube's innards exemplify excellent manufacturing quality—much better than many other LED lights and CFLs (compact fluorescent lights).

The LEDs are in a matrix of 288 diodes in 18 parallel strings with 16 diodes in each string. Each LED has a drop of approximately 3.2V, totaling approximately 50V across the array. The specifications state that the light is 18W, so each string consumes about

Figure 3 The T8 balances cool-white LEDs in the outside rows and warmer-white LEDs in the center row to determine color.

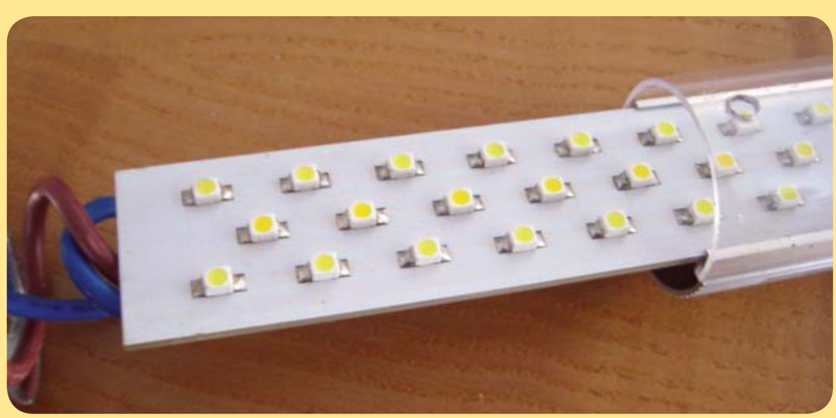
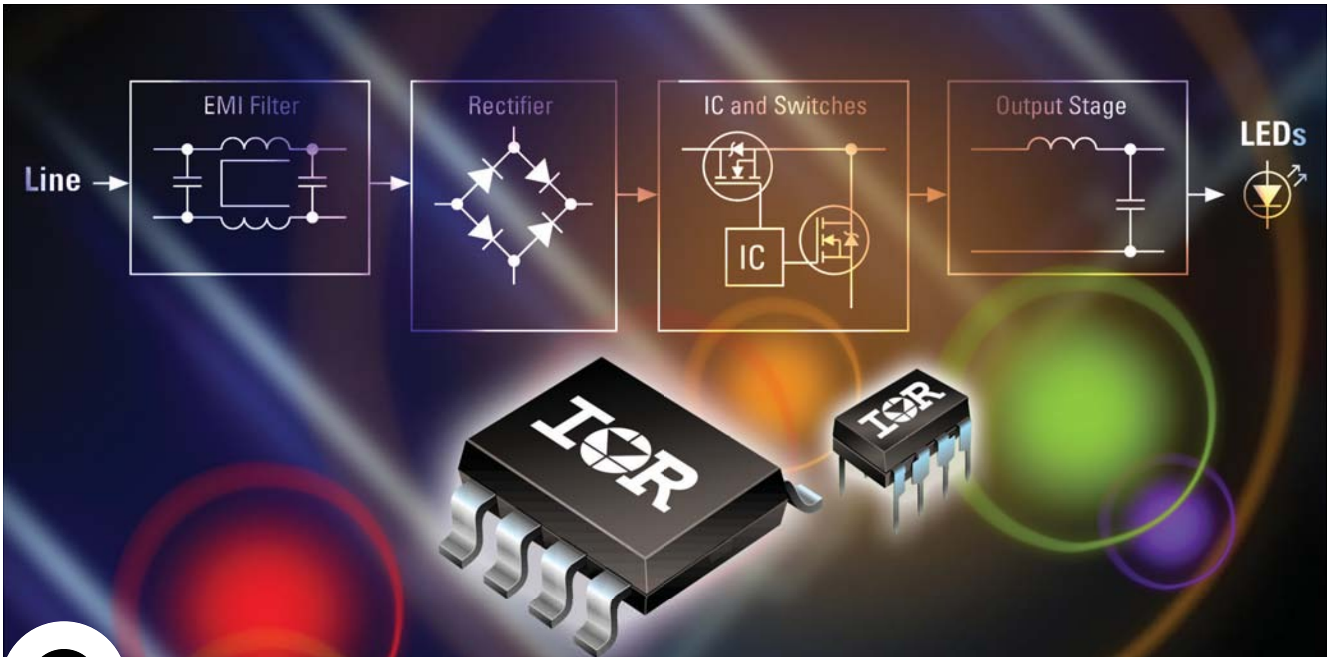


Figure 4 The T8's end cap routes ac power down to the tube's internal power supply.



Precise, Reliable, High Brightness LED Driver ICs

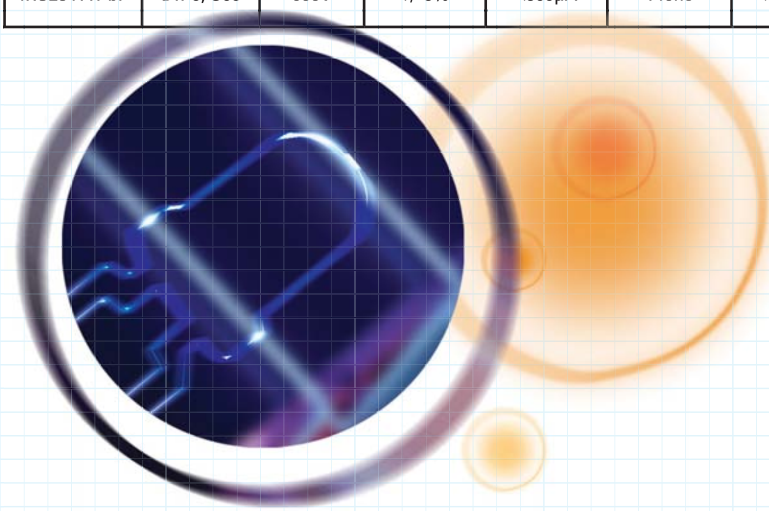
For Constant LED Current Regulation

Part No.	Package	Voltage	Load Current Regulation	Micro-power Start-up	Deadtime	Frequency
IRS25401PbF	DIP8, S08	200V	+/-5%	<500μA	140ns	<500kHz
IRS25411PbF	DIP8, S08	600V	+/-5%	<500μA	140ns	<500kHz

IR's high-brightness LED driver IC's, adapt and compensate to LED parameter variations to enable a highly accurate and inherently stable design.

Features

- 200V or 600V control IC in compact 8-pin DIP or SO package
- Incorporates continuous mode, time-delayed hysteretic buck regulator
- External high-side bootstrap circuit delivers frequencies up to 500kHz
- Micro-power startup of less than 500μA
- 140ns deadtime for continuous current regulation
- Auto restart, non-latched shutdown and PWM dimmable capability



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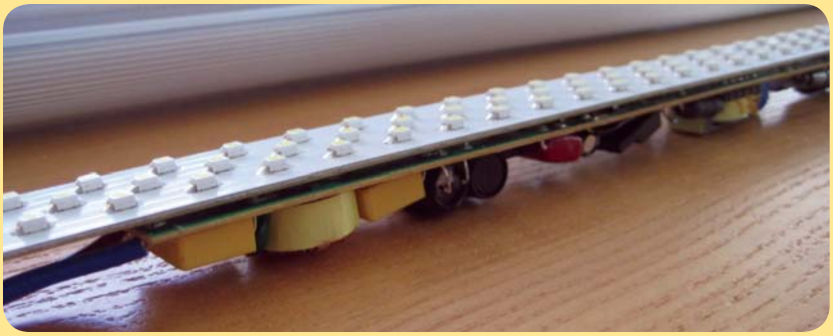

Figure 5 The light's internal power supply extends halfway along the back of the LED PCB.

Figure 6 The five electrolytic capacitors (right) represent potential failure points in the design; you must derate them for use at higher temperatures.

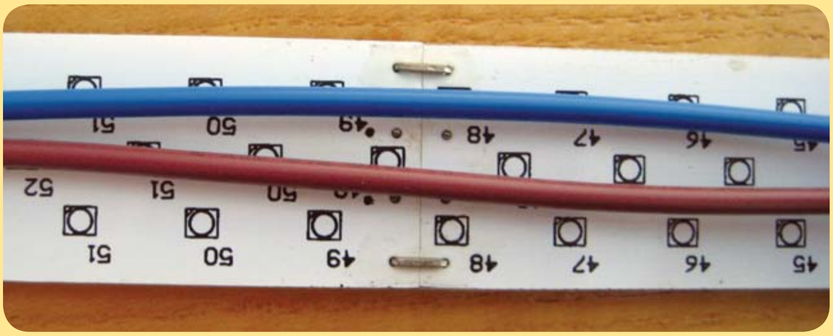

Figure 7 Two stapled short boards comprise the longer PCB.

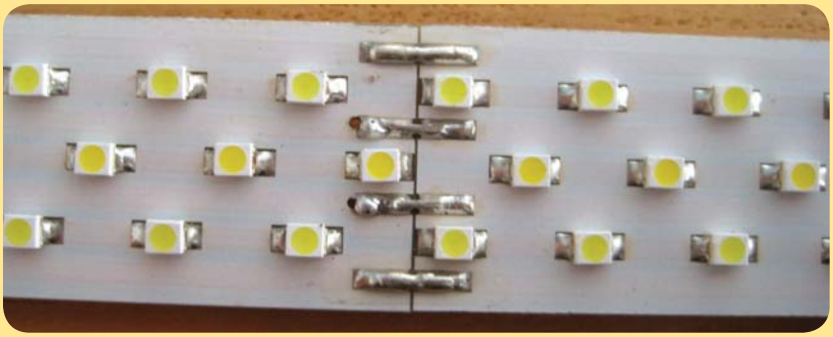

Figure 8 A top view of the boards shows the staples and jumpers that connect the boards.

1W, meaning that each diode uses approximately 0.0625W. This figure is a far cry from the HB (high-brightness) LEDs that you usually encounter in designing for LED lighting, which use approximately 0.5 to 1W.

The power supply apparently outputs 51V dc—that is, although it measures 51V dc at the load, it could be a constant current rather than a regulated-voltage power supply. Regardless, all of the diode strings are paralleled across the power-supply output—not an ideal load for an LED matrix because, as LEDs age, their current profiles change. In an array like the one in **Figure 9**, the string with the lowest resistance pulls the most current, heating the diodes and yielding differences in LED output. One of the most important characteristics of a light source is an even, consistent intensity and color; a matrix such as the one in this **figure** is asking for hot spots. A better choice would be a constant-current driver for each string (**Figure 10**).

Many power-management-IC vendors have developed their own LED-driver chips, such as Texas Instruments' C2000 DSP-based IC driver, which lends itself well to applications with several strings. National Semiconductor, International Rectifier, Marvell, NXP, NEC, On Semiconductor, and several others also offer LED-driver chips, but the C2000 uses a DSP core with multiple PWM (pulse-width-modulated) outputs; one chip can provide a constant-current source for as many as seven LED strings.

You may be thinking that 18 strings would require 18 control loops. This requirement would be a problem for a cost-constrained tube light. Why not dispense with those wimpy 0.0625W LEDs and use some HB LEDs that will each put out 0.5W? Then you would need to use only 36 HB LEDs. This approach brings up a couple of other constraints, though. For example, 0.5W HB LEDs provide distinct, intense-point sources of light, and lighting designers and consumers alike don't want that type of illumination. In addition, HB LEDs of this power have heat-dissipation issues: The 288 0.0625W LEDs

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more uniformly disperse heat and can use an inexpensive PCB. Using fewer high-power LEDs, however, requires a heat-dissipating substrate and may require the use of heat sinks, increasing the price of the tube light.

This design uses fewer expensive LEDs, power-management devices, and intense-point sources of light, but it has uneven current sourcing because LEDs age unevenly, which affects light quality and reliability. The challenge for an LED-based T8 LED-replacement light is to cost-effectively replace today's $2 fluorescent light and maintain the quality of light. Prices for the Alpine T8 tube light range from $65 (1000) to $95 (one) per tube.

Alpine can find customers, even though its tube is competing against $2 fluorescents, because LEDs' longer life can justify their higher costs in some difficult-to-reach applications when you consider replacement costs, including labor, downtime, and difficulty of access. Early adopters who value the color quality of LEDs and who simply like having the latest in technology also may be willing to pay the premium.

You can't consider the tube light as a true replacement of a fluorescent light because of the modifications you must make to a fluorescent-light fixture. An example of a true replacement light for a 40W incandescent bulb is Home Depot's recently introduced EcoSmart dimmable LED bulb (**Reference 1**). The 8.6W light sells for $20 and comes with a five-year warranty. The light provides warm, diffuse light; dims nicely; and produces no noticeable au-

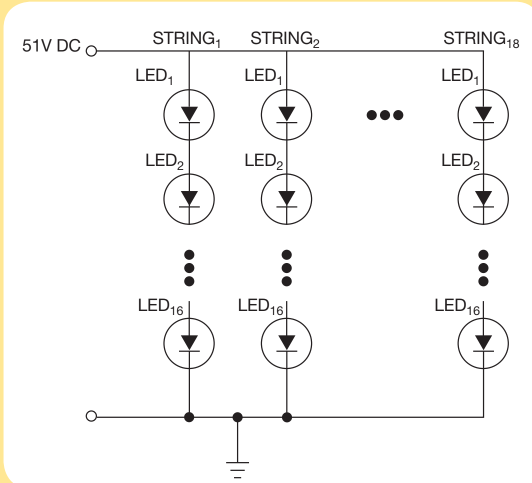

Figure 9 In a multistring LED array with one power source, the string with the lowest resistance pulls the most current.

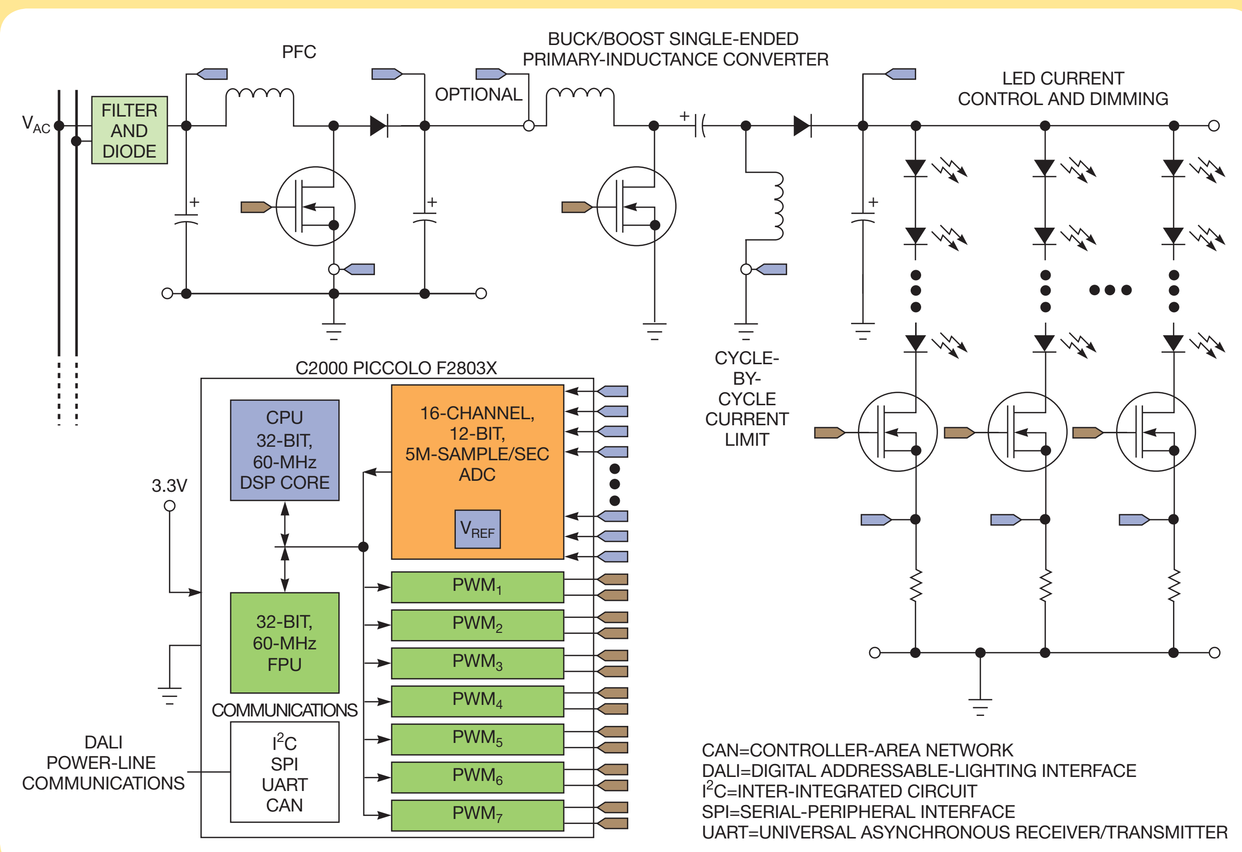

Figure 10 A constant-current driver for each LED string is a better power topology for LED matrixes.

Figure 11 The EcoSmart bulb has a glass outer shell that doesn't easily disintegrate.

Figure 12 An LED bulb from TESS Corp has multiple intense-LED sources; two of them output 429 lumens at 8.6W.

dio noise. It has a glass, dome-shaped outer shell that covers the LEDs and that doesn't easily come apart, as you can see in **Figure 11**. The LEDs are not the usual intense light sources you see in other LED lights, such as the nondimmable, 7.5W bulb from TESS (Topco Energy Saving System) Corp that I disassembled in March (**Reference 2** and **Figure 12**). That light uses seven LEDs that output 560 lumens, according to the specifications on the packaging. These large-surface-area LEDs provide a pleasant, diffuse light source, and only two of them output 429 lumens at 8.6W.

Figure 13 shows a close-up of the EcoSmart LEDs: I removed one to look for a manufacturer's label or mark because officials at LSG (Lighting Science Group), the bulb's designer, don't want to divulge the company's suppliers. I couldn't find a manufacturer's label, but there is an apparent part number, AM6L1, and the part looks like an LED array, meaning that the LED packages several tiny LED chips in one package and covers them with a single phosphor. It's a good choice to use such a diffused light source because there is no pixilation.

To determine whose LEDs the light uses, I perused an LED catalog from Japanese LED manufacturer Citizen (**Reference 3**). It looks as though AM6L1 is similar to Citizen's 6W CCL-L251 LED. In other words, the LSG derates the bulb's two LEDs and runs them at

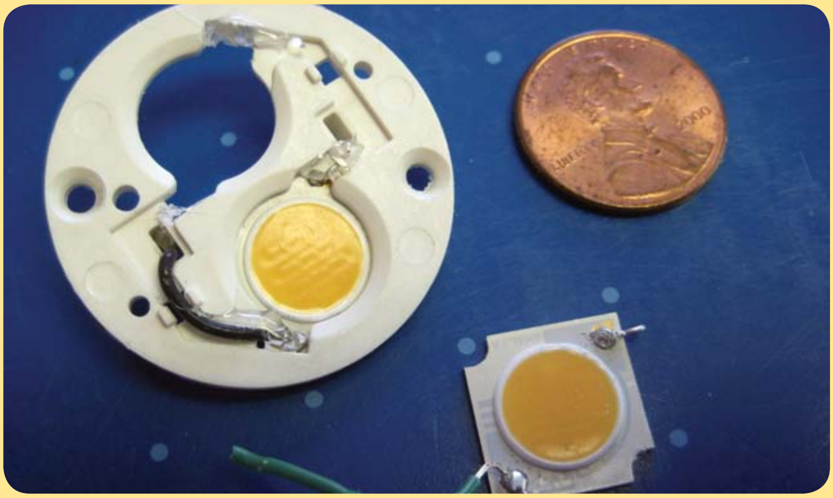

Figure 13 The EcoSmart LEDs have a large surface area that provides a pleasant, diffuse light source.

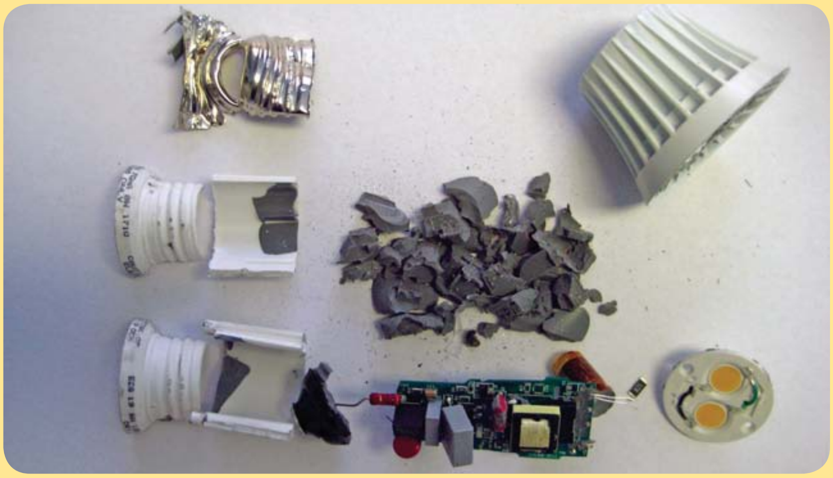

Figure 14 Removing the encapsulant that surrounded the EcoSmart's drive electronics was messy, but surprisingly easy.

less than 6W each—a smart, conservative design choice.

A rubbery compound encapsulates the electronics—a good choice for lighting technology because encapsulation cushions the electronics from all the vibrations inherent in a small, easily accessed light bulb (**Figure 14**). It's not so nice for a tear-down, however. Nevertheless, the rubbery encapsulation material comes off fairly easily, exposing all of the drive electronics. The most promising IC—that is, the one with the most leads—is a 10-pin MSOP with a cryptic "SULB" marking on the top (**Figure 15**). A quick Google search reveals SULB as the "top mark" for National Semiconductor's LM3445 TRIAC (triode-alternating-current)-switch-dimmable LED driver (**Reference 4**). I could see only one 50-µF Nichicon electrolytic capacitor, which operates at 105°C. The black capacitor-like components in the **figure** are inductors.

The electrolytic capacitor, which is partially visible in the right side of the **figure**, is a potential weak link, and this design uses a high-quality part to mitigate the risk of failure. The solder joint is the Achilles' heel of LED-lighting reliability (**Reference 5**); using a highly integrated LM3445 LED driver

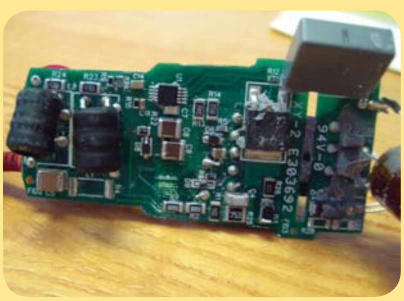

Figure 15 "SULB" indicates that the LED driver for the EcoSmart bulb is National Semiconductor's LM3445 TRIAC-switch-dimmable LED driver.

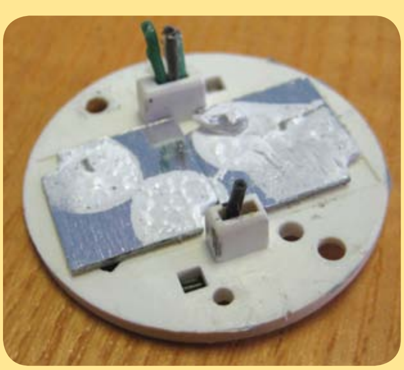

Figure 16 The bottom of the LED base-plate shows the LEDs with a dab of thermal grease on their substrates.

decreases the number of solder joints. The metal baseplate of the LEDs mounts directly on the finned metal heat sink using a dab of thermal grease (**figures 16** and **17**).

Compare this approach with the seven-LED light from TESS, in which the LEDs sit on a metal-core substrate and then on a flexible thermal interface before mounting on the heat sink. EcoSmart uses a simple approach that quickly removes the heat from the LEDs. Its overall design philosophy increases reliability by reducing the parts count and, thus, the associated solder points.

These two tear-downs have been of lights that comply with a lighting form factor. For my next project, I'll take a look inside a new lighting engine from Cree, a manufacturer of LED components. You can think of the Cree LMR4 module as a light engine that can serve as a building block for a lighting luminaire (**Figure 18** and **Reference 6**). You can quickly disassemble this light by removing several screws. A large, white-metal hood encloses the entire device (**Figure 19**). The back of the LED unit lies to the right of the penny, and the light cover is above the unit. The cover has a simple paper cone that serves as a reflector, and a diffuser sits between it and a clear-plastic light cover.

Cree's TrueWhite color-mixing technology combines discrete white and red LEDs. Other approaches to creating a consistent warm white from LEDs rely on combining multiple colored emitters in one LED package or by tweaking the phosphor. The LMR4's TrueWhite implementation has five white LEDs and three red LEDs. When you turn on the light and gradually turn up the power, the four primary white LEDs and the two primary red LEDs come on somewhat uniformly (**Figure 20**). As you continue to crank up the power, the secondary white one and then the secondary red one turn on. If you crank it all the way up, the secondary white LED comes fully on and rivals the primary white LEDs in brightness, whereas the secondary red LED never appears to turn on much at all. Plus, if you leave the light on at a power level in which the fifth white LED initially is off, it comes on after a couple of minutes, which perhaps means that the LED lights' color changes with temperature and that the other two are balancing LED-color changes for both temperature and power. Cree's marketing videos refer to "active color management" when describing TrueWhite, so the power and thermal response must be the active part.

An eight-pin TI 9C L2903 dual differential comparator sits next to the LEDs. This chip perhaps compares the current through the main LEDs and turns on the secondary color-balancing LEDs when the current exceeds a maximum threshold (**Reference 5**). **Figure 21** shows the substrate after it has popped off the baseplate, displaying the metal core. The marking on the front, "Berg MP A2," looks like a Bergquist Thermal Clad metal-core substrate,

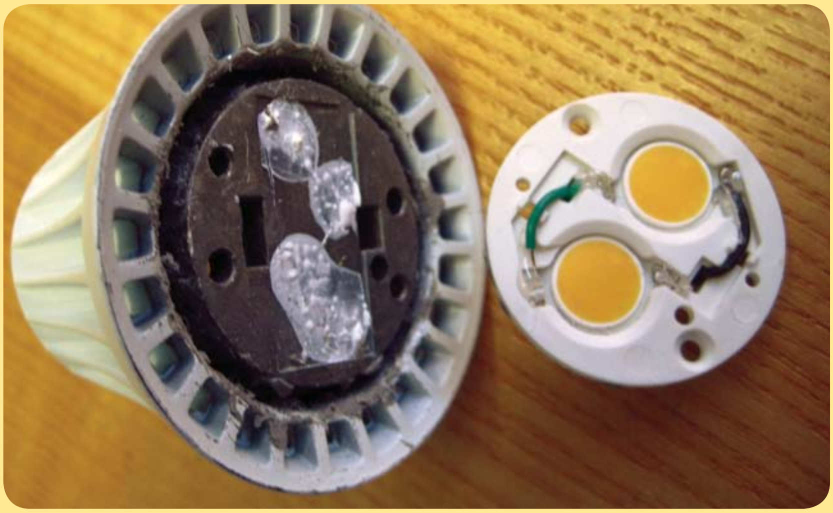

Figure 17 The baseplate of Citizen's LED mounts directly on the large metal heat sink.

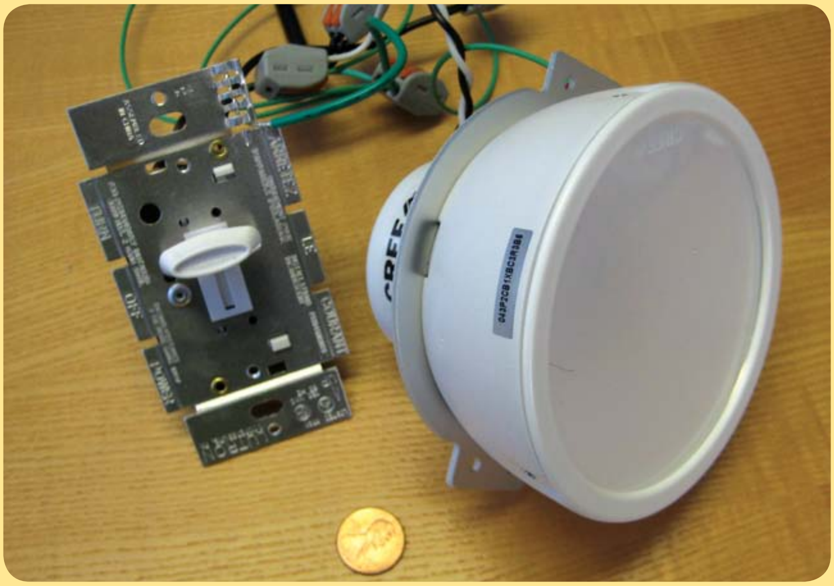

Figure 18 You can quickly disassemble Cree's LM4 light engine by removing several screws.

which comprises a circuit layer over a dielectric layer over a base-metal layer. The substrate clamps onto an adhesive, thermally and electrically conductive layer to the baseplate of the power supply (**Figure 22**). The National Semiconductor LM3445 TRIAC-dimming SULB is probably the power-management IC, and the capacitors are 22-μF, 200V, 100°C Nichicon devices. The power and ground wires loop through a large ferrite bead to filter noise.

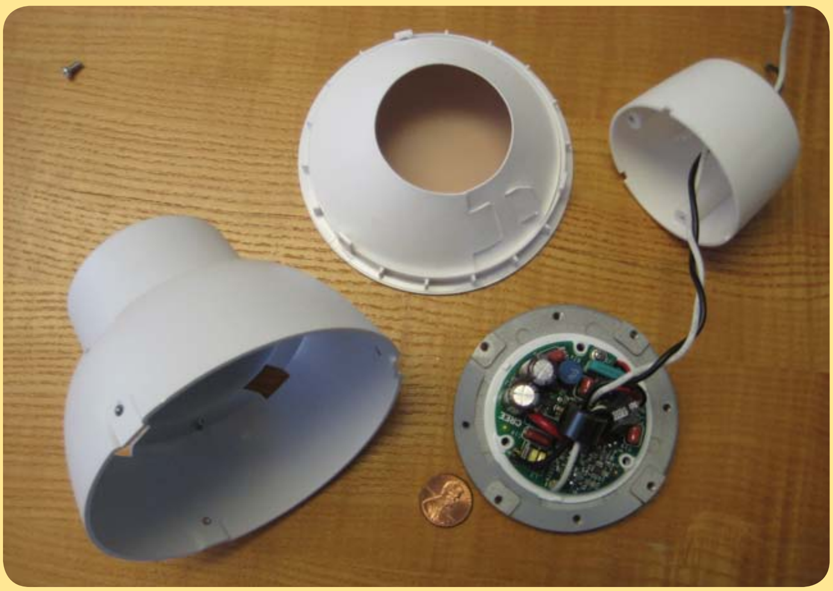

Figure 19 A large, white-metal hood encloses Cree's LM4. An LED unit lies to the right of the penny, and the light cover sits above it. The cover has a simple paper cone that serves as a reflector; a diffuser sits between the cone and the clear-plastic light cover.

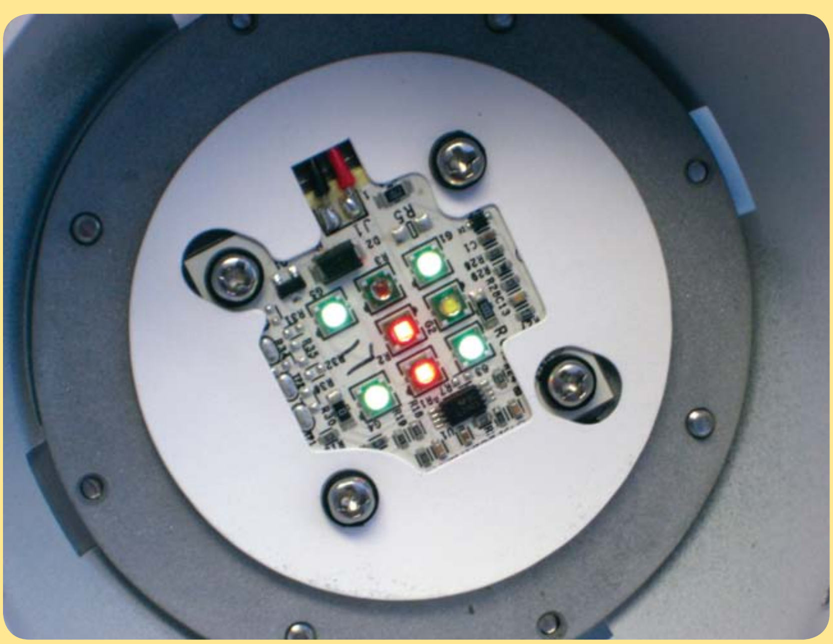

Figure 20 Cree uses five white LEDs, which appear yellow when off, and three red LEDs to perform active color management.

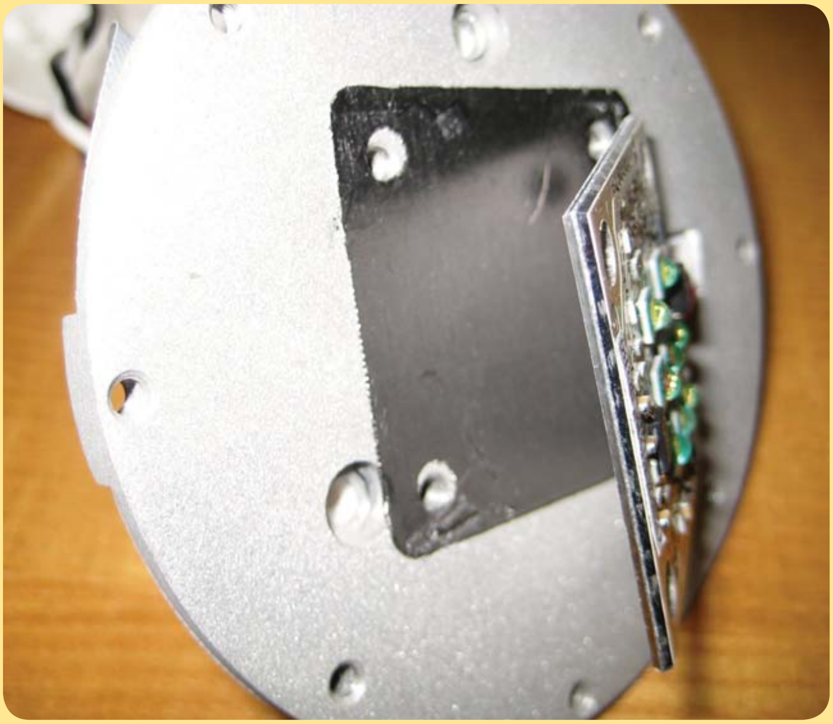

Figure 21 The LEDs sit on a substrate with a metal core and clamp onto an adhesive, thermally and electrically conductive layer to the baseplate of the power supply.

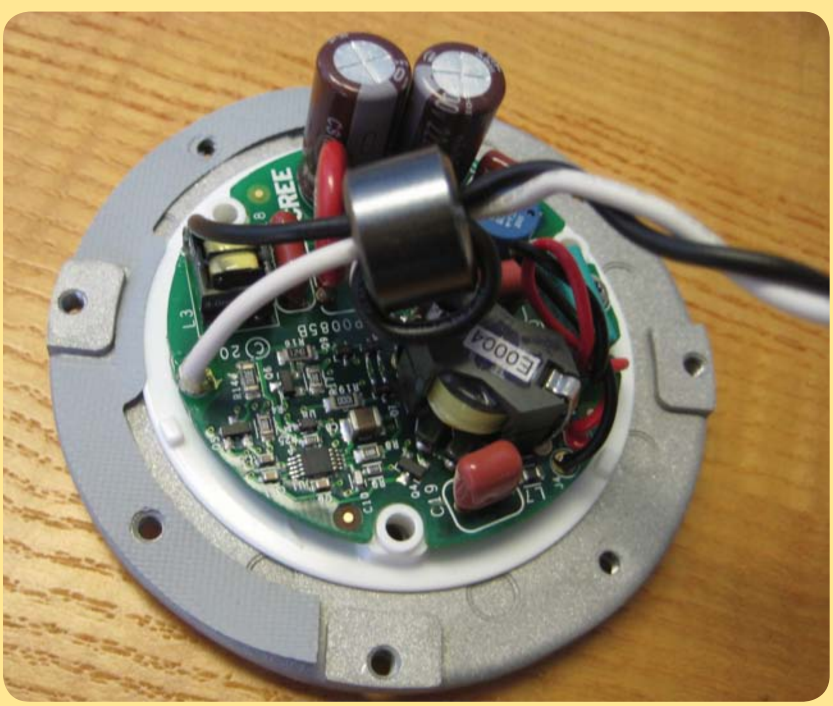

Figure 22 This power-management IC is most likely National Semiconductor's TRIAC-dimming LM3445, and the capacitors are 22-μF, 200V, 100°C Nichicon devices. Note that the power and ground wires loop through a large ferrite bead to filter noise.

Cree specifies the power factor of the LMR4 module at greater than 0.80 for 120V ac/60 Hz, or more than 0.90 for 230V ac/50 Hz. Measuring with my trusty $20 Kill A Watt power meter from P3 International yields a power factor of 0.56. Granted, the Kill A Watt is not the most sophisticated power meter going, but 0.56 is a far cry from 0.8. Removing the Lutron dimmer from the circuit causes the module to operate directly off ac-line voltage, increasing the power factor to 0.91, so the TRIAC dimmer is evidently not fully on even when the switch indicates 100%.

The previous tear-downs were all production-LED lights currently for sale. The next example is a Helieon demo unit from Bridgelux (**Figure 23**). Bridgelux and Molex teamed up to design a socket-and-module combination for new installations (**Figure 24**).

THE HELIEON MODULE INCLUDES A BRIDGELUX LED ARRAY MOUNTED ON AN ALUMINUM SPREADER, A LENS, AND A SOCKET.

The Helieon module includes a Bridgelux LED array mounted on an aluminum spreader, a lens, and a socket. The LED array can deliver 500 to 1500 lumens in 3000K warm white or 4100K neutral white, and the module's optics shape the light path to deliver narrow, medium, or wide flood-beam angles. You can change the white-light unit's color temperature and beam focus by swapping out the LED module. The socket attaches the LED module to the ceiling or the wall and delivers power to the fixture. The Helieon lacks the heat sinking necessary for a fully functional light; I suspect that this omission is the reason that it has a momentary on switch: to prevent evaluators from turning on and leaving on the evaluation kit, resulting in overheating. The Helieon design also

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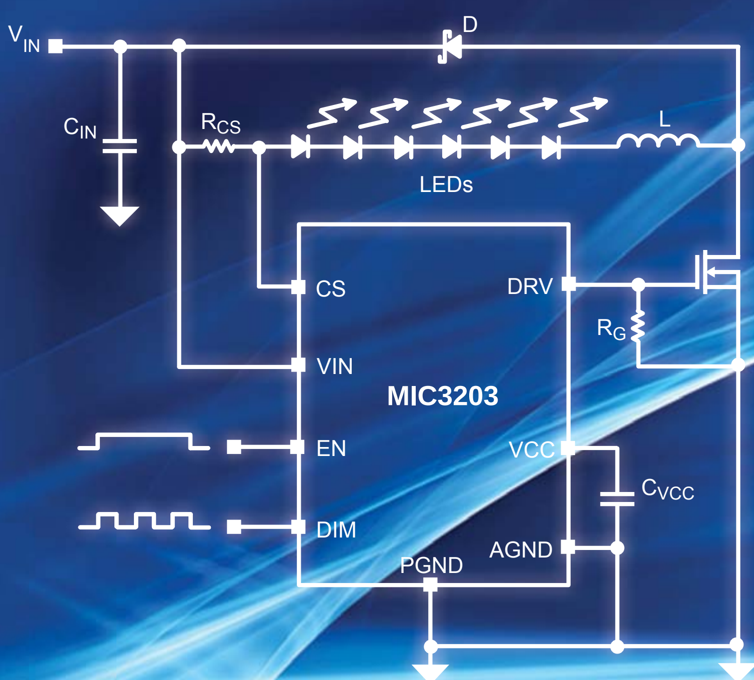

Applications

The rapid growth of LED lighting applications in commercial, industrial and automotive markets has led to a wide variety of technical requirements for LED drivers. Micrel is meeting these challenges with simple step-down LED Drivers such as the MIC3203. The MIC3203 is a hysteretic step-down constant-current High-Brightness LED (HBLED) driver capable of driving multiple HBLEDs. The device provides a low cost solution for interior/exterior lighting, architectural and ambient lighting, LED bulbs, and other general illumination applications. In addition to the high-side current sense scheme, the MIC3203 also offers a dedicated PWM dimming input, a dithering feature for EMI reduction, in an 8-pin SOIC package.

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MIC3203-1	4.5V to 42V	Controller	Yes	No	SOIC-8L

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Figure 23 Bridgelux and Molex teamed up to design a socket-and-module combination for new installations.

Figure 24 The Helieon module includes a Bridgelux LED array, a lens, and an aluminum spreader.

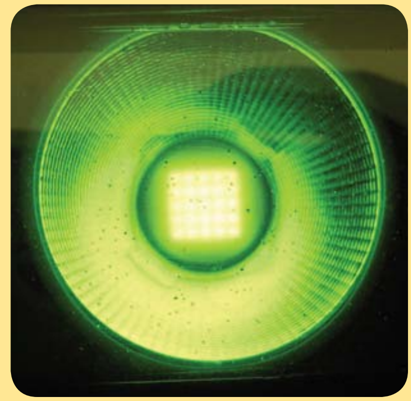

Figure 25 When you look through green welders' goggles, the arrays of emitters in an LED show faintly.

lacks power-management circuitry, but it serves as another example of LED emitters for LED lighting. Bridgelux LEDs package a matrix of LED emitters into one LED device, an approach that's similar to—but on a larger scale than—the one that Citizen LED takes in the EcoSmart bulb. The Bridgelux device provides as many as 1500 lumens in this package (**Figure 25**).

Bridgelux intends the demo unit for designers who want to evaluate the Helieon LED module-and-socket combination; the power-management circuitry is there only to enable the demonstration of the Helieon module. Nevertheless, it illustrates that the power management for LEDs is not trivial. The unit audibly ticks whenever you plug in the brick and hums when you hold down the momentary power switch. The dimmer circuit doesn't use a TRIAC and dims the light by only approximately 50%, rather than virtually off. "Power management is the bane of my existence," says Jason Posselt, vice president of sales for Bridgelux, commenting on these undesirable characteristics and likely voicing the thoughts of many other LED manufacturers.**EDN**

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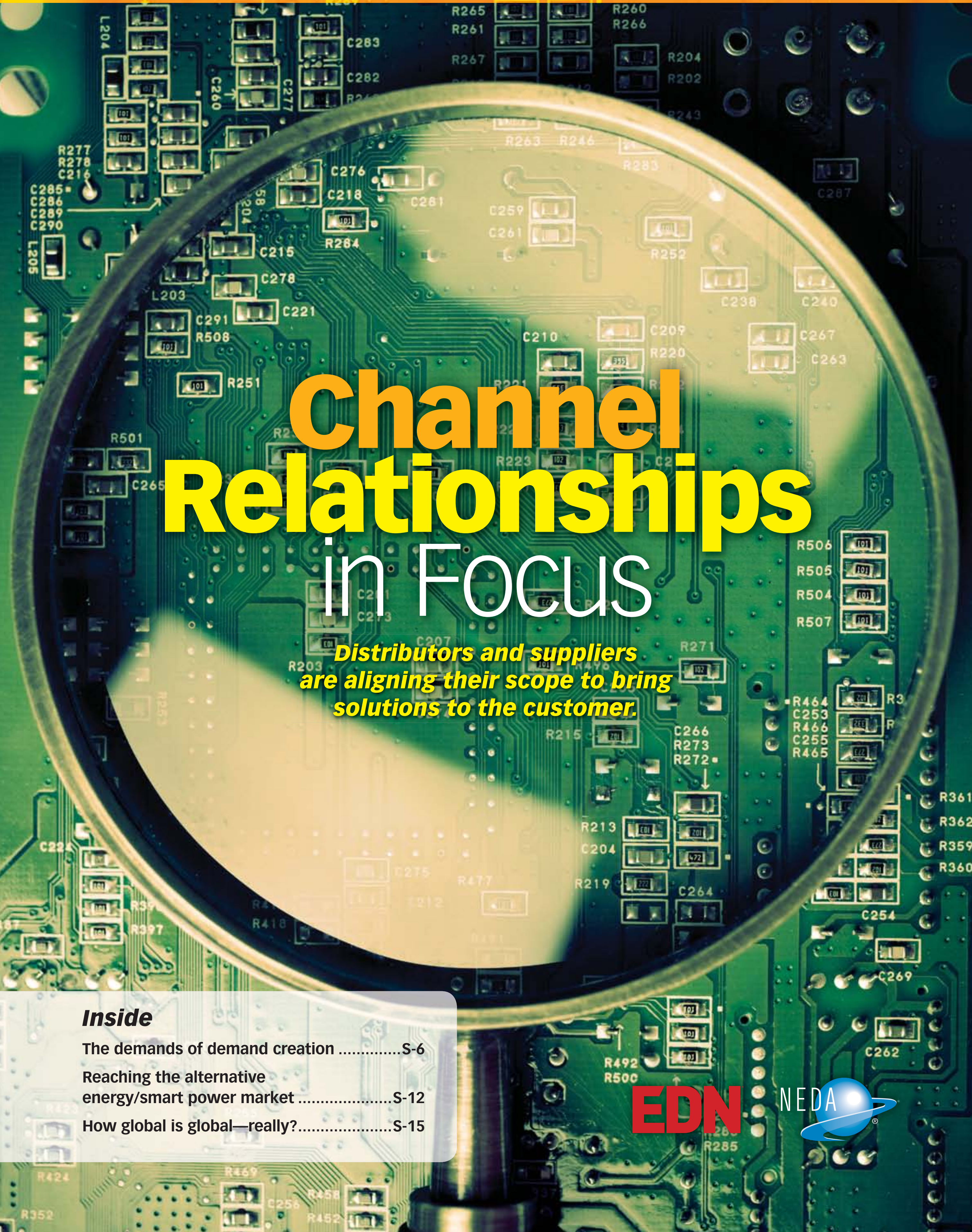

Channel Relationships in Focus

Distributors and suppliers are aligning their scope to bring solutions to the customer.

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A LETTER FROM THE EDITOR

Supply chain relationships in focus

By **Barbara Jorgensen**

The success of the electronics supply chain for years has depended on relationships: supplier-to-distributor-to-customer, and somewhere in the mix add EMS (electronics manufacturing services) providers. In 2010, these relationships are more important than ever. Each link in the electronics supply chain is facing challenges brought on by the economy, globalization, and new market opportunities. While everyone agrees the supply chain has to pull together, each constituent—supplier, distributor, OEM, and EMS—has to look after its own business interests. Things are moving in that direction, but as a number of executives said during interviews for this supplement: "There's still room to improve."

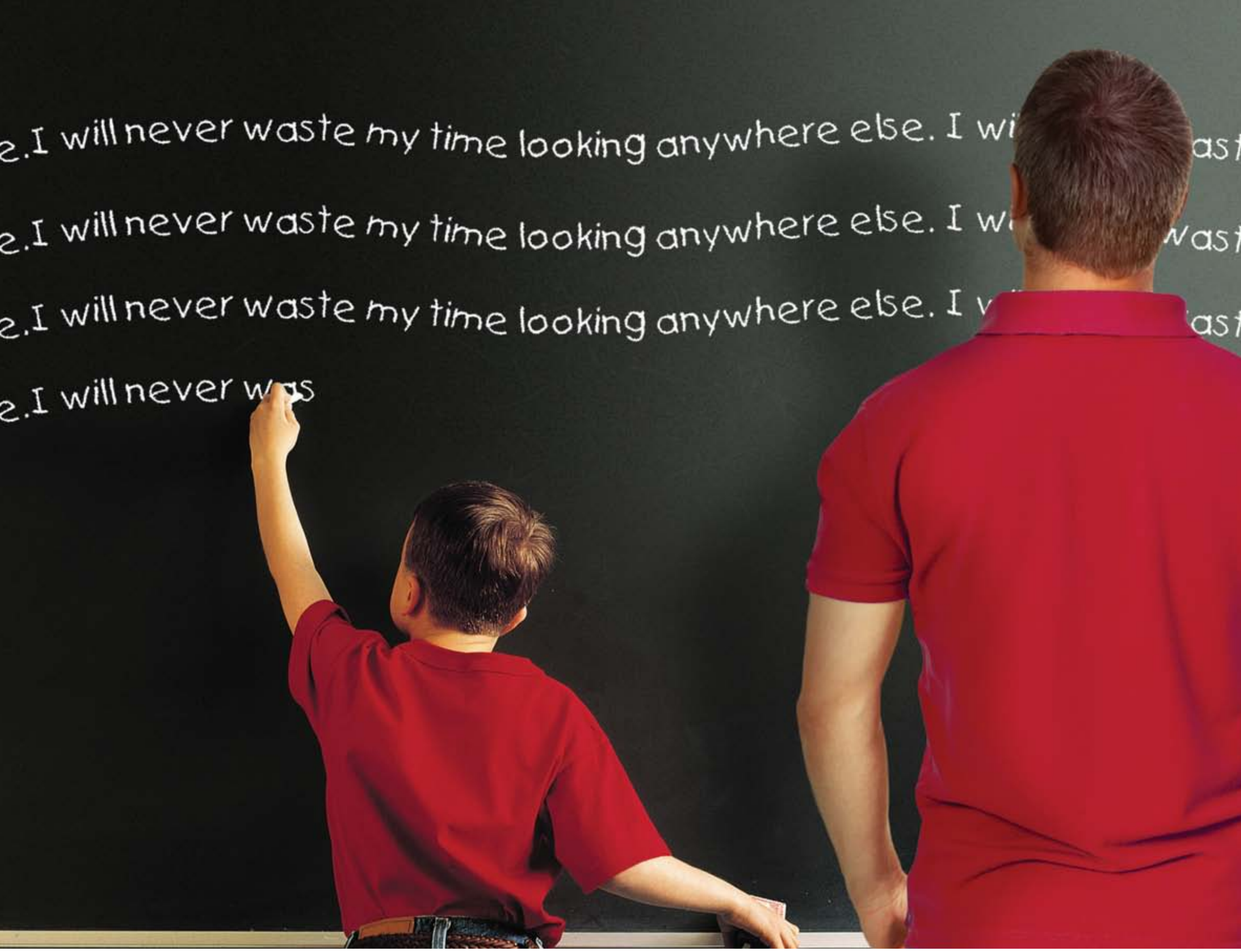
The electronics supplier base has a number of challenges its channel helps to address. In the semiconductor market, the former broadline suppliers—the Motorolas, National Semiconductors, Fairchilds, and Texas Instruments—are dividing into specialty business. Some of these businesses are spin-offs; others are putting more resources into their core competencies. Either way, these suppliers must gain the mindshare of all their channel partners, convey the value of their technology, and win the customer's heart and mind. While there has been less dramatic change in the IP&E supplier base, vendors are equally concerned with their channel partners' focus.

Distributors are well aware of their charter and are responding accordingly. Their efforts are focused on taking suppliers' technologies and providing a full solution. This differs somewhat from the supplier-centric approach practiced before: Instead of promoting one product from one supplier, it takes a "village" of suppliers to provide a solution. Reaching design engineers is paramount to the success of this strategy, yet booking a sale when a design reaches production cannot be overlooked.

There are a number of structural changes in the electronics market that could make things simpler. Global pricing is one of them. Philosophically, the supply chain agrees global pricing is a good idea. Achieving that goal involves not only the supply chain but also geographic business practices, the regulatory system, and regional currencies. Yet some companies are moving toward that goal—with the support of their fellow supply chain members.

So the upshot for 2010—as the industry seems to be leaving the recession in the rearview mirror—is that relationships in the supply chain are getting better. They are coming into focus. But there's still room for improvement. ●

Barbara Jorgensen has been covering the electronics distribution industry for nearly 20 years, most recently as a senior editor at Electronic Business *magazine.*


I will never waste my time looking anywhere else.
I will never waste my time looking anywhere else.
I will never waste my time looking anywhere else.
I will never was

The demands of **demand creation**

Channel partners have to pull together.

By **Barbara Jorgensen**

"There's always room for improvement."

Electronics component suppliers and their distributors both use that phrase when discussing demand creation programs. Although "creating demand"—where distributors help suppliers get components designed into an end product—benefits all members of the supply chain, aspects of these programs are difficult to manage.

"Demand creation is still one of the most profitable portions of our business and has grown significantly to almost 30 percent of our semiconductor sales," says Ed Smith, president of Avnet Inc's Electronics Marketing Americas business unit. Component suppliers offer various incentives for distributors to call on design engineers—higher sales margins, advantageous pricing, or a sales commission on a production order. Distributors, in turn, provide useful information to suppliers: which customers are using their products, what end markets these customers are involved in, and which products are gaining traction.

So why are these programs so complicated? For suppliers and distributors, the issues are more structural than philosophical. In order to compensate a distributor for a design win, suppliers must track an individual component from the design phase through volume manufacturing. Because that product more often than not passes through an EMS (electronics manufacturing services) provider, tracking isn't easy: EMS companies frequently aggregate components into a common pool and use their own identification systems to track them. Those components are then shipped to a number of different facilities offshore.

Suppliers and distributors acknowledge that it takes a lot of collaboration to make demand creation programs work. "We are tightening the circle," says Andrew Femrite, manager of Arrow Electronics Inc's Engineering Solutions Center. "We are realizing that unless we work more closely together and collaborate, we'll never get ahead of the curve."

So demand creation programs evolve with the times. "Our suppliers are leaning on us as much as ever to promote their technology, and we are leveraging each other's strengths to point technology toward specific end markets rather than 'spray and pray,'" says Femrite.

Andrew Femrite
Manager, Arrow Electronics Inc's Engineering Solutions Center

How it works

In the classic demand creation model, a distributor calls on a customer, gets a part designed in, and registers that "win" with the supplier. That registration follows the component throughout the supply chain. Once a customer issues a production order, the distributor's compensation is based on the volume of that sale.

"We have a standard demand creation program," says Jennifer Bleakney, vice president of National Semiconductor Corp's Worldwide Distribution and Customer Support. "We have a subset of products that are eligible for demand creation. By that we mean there are resources in place from a technology perspective; there is exposure of our technology to the customer, and our distributors are advocating our technology and solutions to the customer. For that incremental time and investment, we offer the op-

portunity for incremental margin to be earned by our distributors."

Because most compensation programs are tied to the POS (point of sale)—where the component is actually consumed—offshore manufacturing complicates the process. The distributor that won a design in the United States may not be franchised to resell those components in Asia and can't fulfill the production order. Even if they are franchised, there's nothing stopping a customer from buying those components from a competitor. The channel has struggled with this issue for some time. "Because of globalization, you may do the design work in one region but not know where the product is going to be manufactured," says Tom Vanderheyden, vice president of sales, North America, for TTI Inc.

Molex Inc's model assures that a distributor gets credit for the design. "We have had a program for quite some time that's different than most other IP&E demand creation programs," says Eric Sussman, director for Americas distribution for the connector manufacturer. Molex's program is mirrored on Intel's model. "We give our distributors a set of products we'd like to target for design wins. As a connector company, we have a lot of products. So we pare it down and make it reasonable—we focus on our newly released products or the ones that don't have a lot of play in the market."

If distributor A gets a design win, they get a commission even if the volume sale goes to distributor B. "That way, if you design in a part but someone else books the production order, the sales commission will stay with you," says Sussman.

This type of program also eliminates the variables that come with component price. Since component prices tend to be lower in some regions, the sales commission on a production order would also be lower. (See related story on page S-15.) A fixed commission avoids that.

Supplier benefits

Suppliers also benefit from demand creation programs—their products get sold. But component makers also use information from a design registration to spot potential customers or see what products are gaining traction in the market.

"We don't use design wins to identify potential customers—at the time of the design win [the OEM] is already a customer," says National Semiconductor's Bleakney. "We look at the products that are getting traction and look at vertical markets to determine the right markets for our technology. This helps us identify end markets where our technology can help customers create a competitive advantage."

But suppliers can easily be overwhelmed by incoming data. Not every design win turns into a production order. Catalog distributors may sell one registered product to 100 different customers. Suppliers need some way of culling through orders to determine which leads to pursue.

Volume IP&E distributor TTI Inc and sister catalog distributor Mouser Corp are cooperating on a solution to that problem. Although TTI purchased Mouser in 2000, the companies operate as two separate entities. Mouser carries semiconductor products; TTI does not. Mouser targets design engineers; TTI services engineers and purchasing departments. "The business model of a catalog distributor differs from ours," explains TTI's Vanderheyden. Catalogs sell low volumes of parts for rapid delivery, so unit prices tend to be higher. High-volume orders, on the other hand, often carry a discount.

The two distributors do have a number of suppliers in common, however, and are leveraging those relationships.

Through its NBO (New Business Opportunities) Accelerator program, TTI "filters" through thousands of Mouser orders to identify the most promising sales leads. NBO focuses on products that have been released to the market within a predetermined timeframe and/or are identified by suppliers as eligible for design registration. It also looks for orders that promise volume opportunities. Small labs and hobbyists frequently buy through catalog houses but rarely purchase large volumes of products. Suppliers and distributors both have a finite number of resources to call on engineers and customers. So NBO helps narrow leads down to a manageable level.

"It's proven valuable to our suppliers, and through collaboration we help them identify filtered targets of demand that we can follow up," says Vanderheyden.

Reaching design engineers is crucial to both suppliers and distributors. Future Electronics Inc has relaunched its FAI Electronics division, which targets small and emerging customers. "The more I meet with suppliers," explains Lindsley Ruth, FAI corporate vice president, "the more we realize our opportunities in the mass market. Component makers are interested in two things: creating demand within their large customer base while we call on the mass market, and

Ed Smith
President, Electronics Marketing Americas, Avnet Inc

Jennifer Bleakney
Vice President, National Semiconductor Corp's Worldwide Distribution and Customer Support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increasing the number of customers that use their products. Over the last 10 years, catalog distributors have made a lot of headway in growing the customer base for suppliers."

While FAI focuses on small and emerging customers, Future's volume business ensures product is always available. Generally, distributors forecast inventory needs and place scheduled orders with suppliers. Future buys its products outright and places them in stock. "If you think about it, you design a part into a customer's program but you don't know whether it will take off or not. If you don't put product on the shelf and the design does take off, you run the risk of not having product on hand. We minimize that risk," says Ruth.

FAI's focus is dealing with small customers that have not dealt with larger distribution companies. "We want to bring those customers the same level of service—including engineering support—that any other customer gets," says Ruth. At the same time, that's a challenge for the entire channel. Deploying engineering resources is expensive. "We have to be careful to utilize our engineering resources where there is the most potential for return on investment," adds Ruth. "We work with our suppliers to find the best [customer] solutions, but you have to be strategic and make sure there is ROI."

"There is more technology being offered than ever before," says Arrow's Femrite. "There's demand from our suppliers to take their products to market, but our job is to bring [those products] all together in the most meaningful way for the customer. We are collaborating more and more with our suppliers to anticipate end-to-end solutions—not just hardware but software as well."

Suppliers typically train distributors on products and support demand creation efforts. Making a program work, channel players say, requires technology, training, communication, materials, and tools. "When you offer customers a solution, you're essentially saying 'here is our best technology,'" says Ruth. "But ultimately, the customer determines the best supplier for that technology. But there has to be follow-up, communication, and a focus on ROI."

Selling a solution also takes cooperation across a distributor's supplier base. "Over the past couple of years we have had a centralized conference in Denver bringing our suppliers together," says Femrite. "It takes incredible planning and energy, but it puts all of us in a room and we have bred familiarity with them and their products. We expect to see more and more collaboration and more cooperation across our supplier base to get ahead of where the customer needs to be, and have our processes and development tools ready."

"What we are seeing and hopefully moving to is the perfect situation where distributors are becoming much more focused on serving vertical markets," says National Semiconductor's Bleakney. "Also, when they are focused on the linecard they have and in geographies where they are strong, suppliers will be an advocate so the distributor is armed with the best technical solution for our end customers."

But there are always areas for improvement. "Suppliers can help by leveraging their global strengths and tracking business to the extent they are able to—that affects our mindset locally," says Femrite. "For our local teams, if there is a good possibility that [a project] will go offshore, we have to keep our attention [on that] at the forefront. Understanding the business challenges that our customers face and aligning the right combination of technologies adds the most value for our customers." That way, he concludes, suppliers and distributors "can win their hearts and minds—together." ●

Lindsley Ruth
Corporate Vice President, Future Electronics Inc

BENEFITS OF DEMAND CREATION PROGRAMS

Suppliers

- Ability to expose new technology to market
- Test the reception to the product
- Identify sales leads/new customers
- Identify market trends

Distributors

- Bring new technologies to market
- Sell other components around a design win
- Receive a commission or profit from volume orders
- Provide services beyond component sales

Customers

- Early exposure to new technologies
- Engineering support
- Get solutions (rather than single product)
- Filter through various products

Reaching the alternative energy/ smart power market

Some markets could use a power surge.

By **Barbara Jorgensen**

Although news coverage of the BP oil spill in the Gulf of Mexico has receded to the occasional update, alternative energy remains top-of-mind in many segments of the supply chain.

"We are definitely involved in the alternative energy market," says Eric Sussman, director for Americas distribution for connector maker Molex Inc. "We have products that support solar and wind as well as [alternative energies] in the transportation and auto markets." Smart power—technologies that optimize energy utilization—are also on the channel's radar screen. "It's clear that more technology is involved in optimizing power utilization," says Andrew Femrite, manager of Arrow Electronics Inc's Engineering Solutions Center.

But to capitalize on these opportunities, suppliers and distributors have to work together to find the right mix of technologies for the alternative/smart energy market and reach out to an unfamiliar customer base. "Our focus has been on having the right suppliers and the right technologies," says Femrite.

The supply chain serving the alternative energy/smart power market differs from the typical electronics model. Energy distribution—literally, carrying power from its source to the end user—requires cable, wire, and other transmission elements be installed in buildings, homes, and other facilities. Calling on installers, contractors, and, in some cases, architects isn't the channel's typical function. Yet these are the end customer distributors need to reach. "The installation market is served by electrical contractors that might even call on architects, and that's an unfamiliar market," says Sussman.

"Installers play a huge role in technical sales and engineering," concurs Arrow's Femrite. "Forming partnerships and alliances with them is part of the movement into this market." One way Arrow reaches out is through its ACES (Arrow Consulting Engineering Services) program. Arrow engages with third-party experts in the solid-state lighting field through ACES and is operating a similar model in the energy market.

Future Electronics Inc has recently developed Future Energy Solutions, a unit dedicated to alternative energy markets. Similar to Future Lighting Solutions, Future Energy comprises experts in alternative energy/smart power technologies. "[Alternative energy] is a broad customer base, but we are very focused on delivering complete solutions to the market," says Lindsley Ruth, corporate vice president with Future Electronics.

TABLE 1 GLOBAL SOLAR INVERTER SHIPMENT FORECAST (MILLIONS OF UNITS)

2008	2009	2010	2011	2012	2013	2014
0.98	1.36	2.60	5.35	7.91	14.41	23.34

Source: iSuppli Corp, September 2010

Globally, the alternative energy/smart power market is fragmented. Energy use regulations, such as the EU's EuP (Energy Using Products) mandate, differ from region to region. Similar to the medical and military markets, products sold into the energy market have to meet performance specifications. And alternative energy/smart power adoption is happening at different rates around the world.

The Americas are making progress in smart energy and smart metering, says Ed Smith, president of Avnet Inc's Electronics Marketing Americas group. "The metering space has come a long way," he adds. "Also, the Energy Star program has done a lot to raise awareness of energy conservation in the US, but at the same time it hasn't led to consumers scrapping all their existing appliances to replace them with new ones. Over time it will help, but it hasn't yet spurred the market."

"I see a fair amount of solar power and smart grid in the US and Latin America," says Arrow's Femrite. For the electronics supply chain, smart grid opportunities lie in sensing, measurement, and control devices; communications, transmission, and distribution technologies; and intelligent monitoring. In 2009, the US smart grid industry was valued at about $21.4 billion—by 2014, it will exceed at least $42.8 billion, according to market research firm Zpryme. Given the success of the smart grids in the United States, the world market is expected to grow at a faster rate, surging from $69.3 billion in 2009 to $171.4 billion by 2014.

In the solar market, solar inverters—electronic systems that convert the DC power generated by solar panels into the AC power that is needed for local use—are in high demand. Global inverter shipments are set to exceed 23.3 million units by 2014, up by a factor nine from 2.6 million in 2010, according to iSuppli (**Table 1**). Revenue will rise to $8.9 billion in 2014, up from $5.3 billion in 2010.

Alternative/smart energy is gaining a lot of traction in non-US markets. "Europe has made a lot of headway in metering and lighting," says Avnet's Smith. "There's definitely a changeover to compact fluorescent lighting. And solar is still big in Europe and Asia."

In fact, China is experiencing a "boom" in wind power capacity and PV (photovoltaic) installations, according to iSuppli (**Table 2**).

"Thanks to assiduous government support, the China markets for wind power and photovoltaic solar energy—two major green industries in the country—climbed to new highs in 2009, the latest year for which statistics are available," says Isaac Wang, senior analyst for China research at iSuppli. "Overall, the newly energized green initiatives come in the wake of a pledge from Beijing, announced in December 2009 at the Copenhagen World Climate Conference in Denmark, to cut China's carbon emissions in 2020 by about 45% from their 2005 levels. To achieve the target, China has indicated willingness to reduce reliance on noxious coal sources while also bolstering its fledgling renewable energy industries in order to produce cleaner power."

Solar will continue to grow in regions where it's already gained traction, iSuppli reports. Germany is forecast to install 9.5 GW worth of PV systems in 2011—a 43.9% increase from 6.6 GW in 2010. Italy will install 2 GW worth of PV systems in 2011, up 53.6% from 1.3 GW in 2010. The United States will install the third-largest total of PV systems in 2011, at 1.9 GW, up 79.3% from 1.1 GW in 2010. This is down from 152.3% growth in 2010.

For the wind energy market, new wind capacity generated in China amounted to 25,100 MW in 2009—more than double the 12,100 MW of power posted in 2008. China's output last year accounted for nearly one-third of new wind capacity generated worldwide during the same period, iSuppli data shows, and continuous growth in the sector.

A bastion of support for the Chinese wind power market comes from local sourcing regulations. In particular, the state-run National Development and Reform Commission of China has ruled that domestic sourcing rates should make up at least 70% of wind power mills for facilities to gain construction approval. Supply chain executives say that the North American market could use a similar shot in the arm. The US government has stated its commitment to alternative energy, but actual sales have yet to materialize in the channel.

"So far, the market has been very involved in lighting, but the commitments that have been made by the US government haven't taken hold in large quantities," says Molex's Sussman.

TABLE 2 CHINA PHOTOVOLTAIC INSTALLATION FORECAST (MW)

2009	2010	2011	2012	2013	2014
200	580	890	1,350	1,760	2,370

Source: iSuppli Corp, August 2010

How global is global—really?

Global pricing is good in concept but difficult to execute.

By **Barbara Jorgensen**

There are so many aspects of supply chain relationships that are tied to component pricing that it's no surprise pricing is a hot topic. Much of the compensation in demand creation programs is attached to price. (See related story on page S-6.) Many large customers receive a preferred price from suppliers. Global and long-term contracts contain guidelines and targets on price—usually reductions. Even a unique channel accounting practice—ship from stock and debit—is entirely about price. "Price is usually the basis of the [supply chain] relationship," says Gerry Fay, senior vice president, Avnet Supply Chain Solutions worldwide.

The issue of a global price—a single baseline price for a component no matter where it is bought or sold—has been around as long as globalization. Prices vary from region to region because costs differ from region to region. But as the industry has become more linked, more transparent, more decentralized, and more global, moving components around the globe has become a necessary practice. Savvy buyers source products from low-cost regions and deploy them where needed. This has a number of negative implications for suppliers and the channel. Prices could erode to the lowest possible level. As prices erode, profit margins shrink. Incentives for demand creation would shrink so distributors would see less return on investment for engineering efforts. "I would think that manufacturers and distributors are on the same page regarding the pros and cons," says Fay.

The implication has become that global pricing equals lowest pricing. Suppliers and distributors say this is not the case. These channel partners have to continually communicate and cooperate to ensure customers are satisfied with prices while reflecting the realities of conducting business in a global environment.

Some suppliers have developed what they call a "baseline" or "published" global price. "We have a single price worldwide from a published price perspective. We used to have different published prices in different parts of the world, but we have gone to a global price list. It is a much more efficient business process," says Jennifer Bleakney, vice president for National Semiconductor Corp's Worldwide Distribution and Customer Support. "To me, a global price does not necessarily refer to the lowest price; it refers to the fact a customer is able to get the same price in the fulfillment region as the demand creation region," says Bleakney.

Even a single global price fluctuates in channel relationships. Large, preferred customers may receive a contractual price from suppliers that are specific to that customer. Distributors receive discounts based on the volume of products they purchase. So many variables go into pricing that few suppliers are comfortable saying their prices are global.

The variables

One of the biggest variables, says Fay, is how and where a customer wants a component delivered. For a global distributor, different regions have different "overhead" costs (warehousing, personnel, and facilities), transportation costs, payment terms, and other fees. "What happens in price negotiations is that those terms aren't spoken about—the customer expects

Gerry Fay
Senior Vice President, Avnet Supply Chain Solutions Worldwide

Michael Knight
Vice President, Product and Supplier Marketing, TTI Inc

those costs are all built into the price—and the customer is surprised," says Fay. "When a customer and supplier negotiate price, they may not talk about the terms of service—the services the channel provides—and they don't realize that prices depend on such variables as shipping and freight."

Another factor, he explains, is payment terms. Different regions and even different countries may pay in 30 days, 120 days, or even 160 days. "A global price could be managed if we say 'pay cash in 30 days and no terms,' but otherwise there are costs associated with credit transactions," says Fay.

Suppliers and distributors generally agree that a single, global component price would make transactions easier on the channel. "Quoting a BOM would be easier; particularly for a big EMS—right now we have to quote parts in three regions," says Fay. "Design win tracking would be a lot easier—compensation for a design win wouldn't matter if the design was booked in the west but manufacturing went east. It would get rid of ship and debit, which is a big time sink for both distributors and suppliers. I think global pricing would simplify a lot of transactions."

It would also make things easier and more consistent for customers. "Suppliers would be more open to a distributor managing a franchise even if it doesn't have the franchise in a specific region," says Fay, so customers could expect global support. "Having one single price worldwide from the published pricing standpoint helps manage the cost of processes in all regions of the world," says Bleakney.

The biggest concern in the channel is that global price will become lowest price. Theoretically, if a component price is lowest in Asia, that becomes the negotiating point for the customer. This could drive prices down all over the world. For many suppliers, accommodating lowest-price expectations are near to impossible. "We have variable manufacturing costs in every location," says Eric Sussman, director of Americas distribution for connector maker Molex Inc. Pricing, he says, is manageable if a product manufactured in one region is also consumed in that region. However, particularly for a large EMS order, fulfilling that order from a single manufacturing plant is impractical. "Because OEMs use EMS providers and they move everything around the world, we have to sell everywhere," says Sussman. "But that adds freight and duties and to [keep price consistent] you have to know what your cost is to manufacture something in Asia and ship it to the US, or vice versa."

The other concern is that a global price could become the highest price. In fact, because of China's local content laws and tariffs, manufacturing costs might be low, but transferring components out of China is expensive. "In some cases when we quote a BOM, China is the highest price of three regions," says Fay.

The distribution channel has become accustomed to the issue, but that doesn't mean it's easy. "We have always had different prices in different parts of the world, and we've been able to handle that," says Michael Knight, vice president of product marketing and supplier marketing for specialty distributor TTI Inc. "It's not a hardship from our standpoint. Global pricing is driven by the desire by customers and suppliers to simplify things—it is very complicated for a supplier to maintain different prices and different policies when the inventory is constantly moving around the world."

Future Electronics takes some of the variables out of the equation with its "we buy it, we own it" inventory practices. Among other things, it eliminates ship and debit. "We can come closer to a global price," says Lindsley Ruth, corporate vice president for Future Electronics. "We have one inventory system, one IT system aligned on one platform, and one philosophy in every region."

Barriers to global pricing

The industry is still a pretty long way away from global pricing, says Knight. The existing structure of many companies or the business practices of a region would need to be overhauled so everyone competes on a level playing field. In Japan, he says, manufacturing may be done in Asia, but suppliers have warehouses in every region. The factory essentially "sells" its products to the warehouse; the warehouse, in turn, sells to the customer or distributor. In the supply chain, factory-to-distributor or factory-to-customer shipments are most cost-effective because every time a product moves, there's a cost-related markup. "It's a business obstacle if companies have to retool their business models and how they cost things from a factory standpoint," says Knight. "Until everyone is willing to do that, it's impossible to get to a really global price."

Another issue is, in spite of being global, companies track P&L (profit and loss) on a regional basis. Maintaining regional pricing makes sense. "By design, each business unit has to have some kind of metrics, and you have to be able to measure its progress. The only way to do that financially is to create a P&L. It covers sales, credit handling costs, profits, and sales credits etc., and then those have to be divvied up in a prevailing structure. I can't think of anyone that has a truly global structure—everybody is measured on local results."

There is definitely an increasing interest in global pricing, says Andrew Femrite, manager of Arrow's Engineering Solutions Center. "But at the end of the day there are fundamental barriers to global pricing that haven't changed, and we haven't found ways to globally address them."

Ultimately, a true global price is impossible when you don't have true global currency, Knight points out.

"Global pricing is a possibility," says Femrite, "but it won't be in six months. The issue is always on the tip of your tongue—but the devil is in the details."

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Conflict-minerals law spotlights electronics supply chain

A new law requiring companies to disclose whether their products contain any of four "conflict minerals" from the Democratic Republic of Congo or surrounding countries has executives throughout the electronics supply chain trying to figure out how they can comply (**Reference 1**).

The civil war in Congo has killed an estimated 5.5 million people, and the United Nations cites it as the worst global genocide since World War II. Experts believe that armed rebels finance their terror through the illegal sale of tantalum, tungsten, tin, and gold from mines in the area. The Enough Project (www.enoughproject.org, **Reference 2**), an antigenocide group, directly links violence in Congo to the use of these minerals in consumer-electronics products, such as cell phones, computers, and TVs, and has launched a campaign to pressure the makers of these products to eliminate their use of conflict minerals.

The US legislation aims to encourage companies to do more to ensure that minerals in their products do not come from this illegal activity. Congress this summer passed the Dodd Frank Wall Street Reform and Consumer Protection Act (**Reference 3**), which includes a provision that requires public companies that trade on a major US exchange to determine whether their

products use any of the four minerals. If so, the companies must determine and disclose in a report whether any of those minerals originated in Congo or a neighboring country and file the report with the US SEC (Securities and Exchange Commission, www.sec.gov).

If the minerals did come from that area, the companies must note that fact and describe their efforts to determine exactly where the minerals came from—down to the exact mine if possible. Many poverty-stricken people in Congo depend on legitimate mines for a subsistence income; the goal is for companies to continue to receive their materials from those mines and avoid using material from illegal mines.

The legislation sets no penalty for using conflict minerals. By requiring companies to disclose this information, however, it exposes their supply-chain policies and practices to scrutiny, especially from human-rights organizations.

Exactly how this process will all work depends on the regulations that the law directs the SEC to write. Industry watchers expect the SEC to put out proposed regulations for public comment by the end of 2010. Final regulations are due by mid-April 2011. Companies will be expected to issue reports starting during the first fiscal year after the SEC issues the regulations.

Determining whether conflict minerals are in products is a Herculean task. An OEM can trace its components back to certain manufacturers, and those manufacturers may even be able to trace its mineral suppliers back to particular smelters. The trail then goes cold, however, because smelters typically mix together minerals from a variety of sources, including recycled materials. At that point, it's impossible to determine the origin of all the minerals in the metal.

"It's from everywhere and nowhere all at once," says Rick Goss, vice president of environment and sustainability at the Information Technology Industry Council (www.itic.org, **Reference 4**). "There is no single source."

The electronics industry is the major user of tantalum, however, and is making progress in tracking it. For example, the industry is developing an auditing program for tantalum smelters. Once this program is complete, groups will be able to require their component suppliers to use materials only from those smelters that passed an audit.

The sooner electronics companies can take substantial action, the better: Human-rights groups intend to keep a spotlight on this issue. The Enough Project is surveying 21 major consumer-electronics companies to find out what each is doing about the issue. The project plans to use this information to rank the companies' level of activity and next month publish that list on its Web site.

—by Tam Harbert

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productroundup

SENSORS/TRANSDUCERS

MEMS microphone provides omnidirectional sensitivity

The MP45DT01 MEMS digital-output stereo microphone targets use in applications in which compactness, high-quality sound, reliability, and affordability are critical. These applications include cell phones, portable media players, games, digital cameras, security systems, learning devices, and hearing aids. The device provides omnidirectional sensitivity to detect and filter out background noise. Incorporating multiple microphones in one device further improves sound quality. Like other MEMS microphones, the MP45DT meets the price points of traditional electret condenser microphones and uses sensor technology from Omron that is inherently less susceptible to mechanical vibration, temperature variations, and EMI. The device costs $1 (10,000).
STMicroelectronics, www.st.com/mems

Dual-channel bipolar switch has two Hall-effect sensors

The A1230 dual-channel bipolar switch features two monolithic, 1-mm-apart Hall-effect sensors, each providing a separate digital output for speed and direction signal processing. The Hall elements photolithographically align to better than 1 micron. Maintaining accurate mechanical location between the two active Hall elements eliminates the major manufacturing hurdle that designers sometimes encounter in fine-pitch-detection applications. The highly sensitive, temperature-stable magnetic sensing A1230 targets use in ring-magnet-based speed and direction systems in harsh automotive and industrial environments. The A1230's digital outputs are out-of-phase so that they are in quadrature when designers interface them with the proper ring-magnet design. The switches also feature an on-chip low-dropout regulator so that they can operate over a wide voltage range. The A1230 costs 92 cents (1000).
Allegro MicroSystems,
www.allegromicro.com

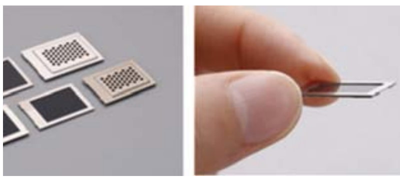
Three-axis accelerometer consumes as little as 2 μA

The three-axis LIS3DH digital-output accelerometer consumes as little as 2 μA of power and provides

output across full-scale ranges of ±2, ±4, ±8, and ±16g. It contains a sensor and three ADC channels. It also features click and double-click recognition; 4- and 6-D-orientation detection; and a power-saving sleep-to-wake-up mode, during which it keeps the read chain active and wakes up when an event occurs, automatically increasing the output-data rate. The 3×3×1-mm LIS3DH sells for 85 cents (100,000).
STMicroelectronics,
www.st.com/mems

Waterproof piezoelectric speaker is 0.9 mm thick

The IPX7-grade, 0.9-mm-thick VSLBG1914E1400-TO piezoelectric speaker features average sound pressure of 92 ±3 dB at 1500, 2000,



2500, or 3000 Hz average, and resonant frequency is 1400 Hz ±20%. Acoustic characteristics include an input of 5V rms sine wave, a speaker-to-microphone distance of 10 cm, and a speaker-back cavity of 0.7 cc. The waterproof speaker costs approximately $2.72 each.

Murata Manufacturing Co,
www.murata.com

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Brute force brings better board

It was Hewlett-Packard's most ambitious desktop computer to date. The HP 9845A had two 16-bit hybrid microprocessors—one for language processing and one for I/O. It also had two internal DC100 digital minicartridge tape drives, a 24-line×80-character CRT display, a page-width thermal printer, and four I/O slots. The machine was a big, expensive gamble, and the Desktop Computer Division needed to get it out into the market ASAP. The only problem was that the HP 9845A's high-profile, high-speed I/O mode had a glitch, and the machine could not reliably "talk" to its optional external 8-in. floppy drive. The 9845 team needed a fix—fast—before releasing it to production.

I came in as a troubleshooter based on my reputation as the division's "I/O guy." One look at my workbench, and you knew I was the right guy. It was filled to overflowing with as much HP test gear as I could squirrel away.

The failing I/O mode was a DMA I/O transfer from the floppy drive into the HP 9845A at the maximum I/O speed of 400,000 transfers/second—less than half a megatransfer/second. The I/O transfers were unreliable over the 6-foot cable between the desktop computer and the external floppy drive.

There was one clue. The much smaller HP 9825A desktop calculator didn't exhibit such glitches when talking to the same HP 9885A floppy drive, thus exonerating the HP 9885A. The problem had to be in the HP 9845A, but how to find it? In 1977, logic analyzers almost hadn't been invented. Those analyzers that did exist had no hope of finding and displaying glitches on a 16-bit data bus transferring data at 400 kHz.

HP's Colorado Springs, CO, division was responsible for developing logic analyzers and had just built the prototype of a new more advanced logic analyzer, the HP 1615A. It had the required speed and could capture all 24 bits (data plus control lines). We borrowed the prototype, adding even more equipment to my bench.

With the right tool, it was a simple matter to find the data-dependent noise glitch on the HP 9845A's I/O bus. The nature of the glitch pointed to a power-supply problem, so I looked at the HP 9845A's I/O backplane, and I got a shock. Each I/O card for these desktop computers was allocated 0.5A on the 5V power bus, for a total of 2A over four slots. The positive and negative 12V supply rails were more limited in current, and, in any case, the HP 98032A's parallel I/O card to connect the HP 9845A to the HP 9885A floppy-disk drive didn't use the 12V supplies. So the problem had to be with the 5V supply rail.

When I looked at the HP 9845A's I/O backplane, I discovered that it was a two-layer PCB (printed-circuit board) and that the 5V bus was distributed to the I/O cards over a relatively thin copper trace. The trace was too thin and presented too high an impedance for the power-supply transients that the "fast" I/O caused. No amount of bypassing was going to help in this situation. It required a more aggressive fix.

The HP 9845A would have a base price of $11,500. With options, the HP 9885A floppy-disk drive, and the required HP 98032A I/O card, the total package price easily exceeded $25,000. Nothing I could do to this I/O backplane would significantly affect the factory cost of the machine. I could have redesigned the board with fatter power-supply traces and left it as a two-layer board. However, the I/O board might have had other problems due to the lack of a ground plane, and I didn't have the time to find out. So I elected brute force in the name of expediency. I left the two PCB layers as they were and I added four more—one for ground, one for 5V, and two for the two 12V supplies. The new I/O board did the trick. The power-supply-delivery modifications killed the glitch with one quick PCB re-spin. HP released the 9845A to production, and it hit its market window. EDN

Steve Leibson is EDA360 evangelist at Cadence (San Jose, CA) and former editor-in-chief of EDN.

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34410A	6 ½	0.0030%	10,000 / sec	2.6 ms	GPIB, USB, LAN (LXI)
34411A/ L4411A	6 ½	0.0030%	50,000 / sec	2.6 ms	GPIB, USB, LAN (LXI)
34420A	7 ½	0.0030%	250 / sec	.02 sec	GPIB, RS-232
3458A	8 ½	0.0008%	100,000 / sec	3.0 ms	GPIB

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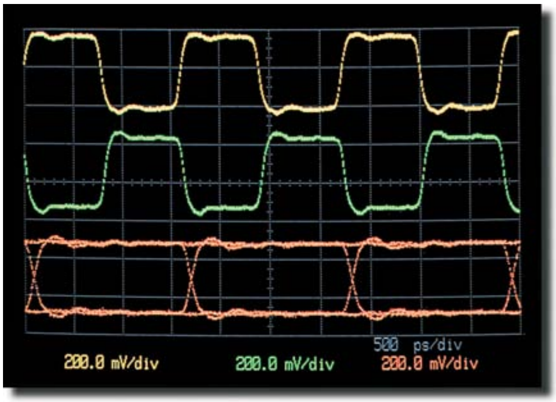

Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

The CG635 generates clock signals—flawlessly. The clock signals are fast, clean and accurate, and can be set to standard logic levels.

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Avago Delivers First "Track on Glass" Laserstream™ Mouse
In the Fall of 2009, Avago again advanced mouse technology by announcing the first fully integrated wireless mouse using Bluetooth™ (BT) 2.1 System-on-Chip (SoC) LaserStream navigation sensor for wireless mouse applications.
This compact, laser navigation sensor engine from Avago, integrates a BT transceiver, stand-alone baseband processor and VCSEL illumination into a single chip package to provide a complete SoC solution that provides fast and secure connectivity, and easy integration into mouse designs.
Looking Back
Significant advances to the "mechanical" mouse occurred in the 1990's when Avago Technologies (then called Agilent) brought the first commercially successful optical mouse to market. The optical mouse sensor used an LED (Light Emitting Diode) and photodiode/pixel array to track the relative movement of the mouse over a surface. This advance made it possible to use a mouse on almost any surface, eliminating the need for mouse pads, and avoided the dirt problem with ball-based mice.
By 2006 we had shipped 600 million optical mouse sensors and in 2009 that number reached one billion sensors.
Innovative Avago RF Technologies Enhance Global Mobile Phone Compatibility
Looking Back
In 1993, Richard Ruby began researching FBAR technology as a means to making high-Q, ultra-miniature filters for RF applications. Eight years later, in 2000, FBAR technology – in the form of PCS duplexers – showed up in cell phones.
By 2004, Avago was awarded it's 100th mobile phone design win for FBAR duplexer and transmit filter.
Avago's innovative Wafer Scale Packaging, enhancement-mode pHEMT, CoolPAM™ and Film Bulk Acoustic Resonator (FBAR) technologies have set new benchmarks for component size, low power requirements and performance.
For example, Avago's FBAR based quintplexer utilizes five FBAR filters to produce a totally passive solution for dual-band cellular communications with GPS. The module directs PCS and cellular signals from the same antenna without the use of switches and control logic, eliminating the cost and electrical loss of the switch, as well as routing and matching losses, and the space required for this functionality.
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2009 • First GPS front-end modules with FBAR pre-filter and Low Noise Amplifier (LNA)
• Unveiled advanced embedded optical engine technology to enable high-speed connectivity
• First Bluetooth™ 2.1 System on Chip (SoC) LaserStream™ sensor
• World's brightest 5mm through-hole round LED
2008 • Industry's smallest Field Effect Transistors (FETs)
• First 10 Gbps Ethernet SFP short reach transceivers
2007 • First demonstation of 100 Gigabit Ethernet parallel optics
• Smallest RF front-end module for Global Mobile Band handsets
• First miniature reflective analog optical encoder
2006 • One-millionth fiber optic transceiver shipped
2004 • First multi-channel/bi-directional optocoupler
2000 • Industry's first 3.3V optocouplers
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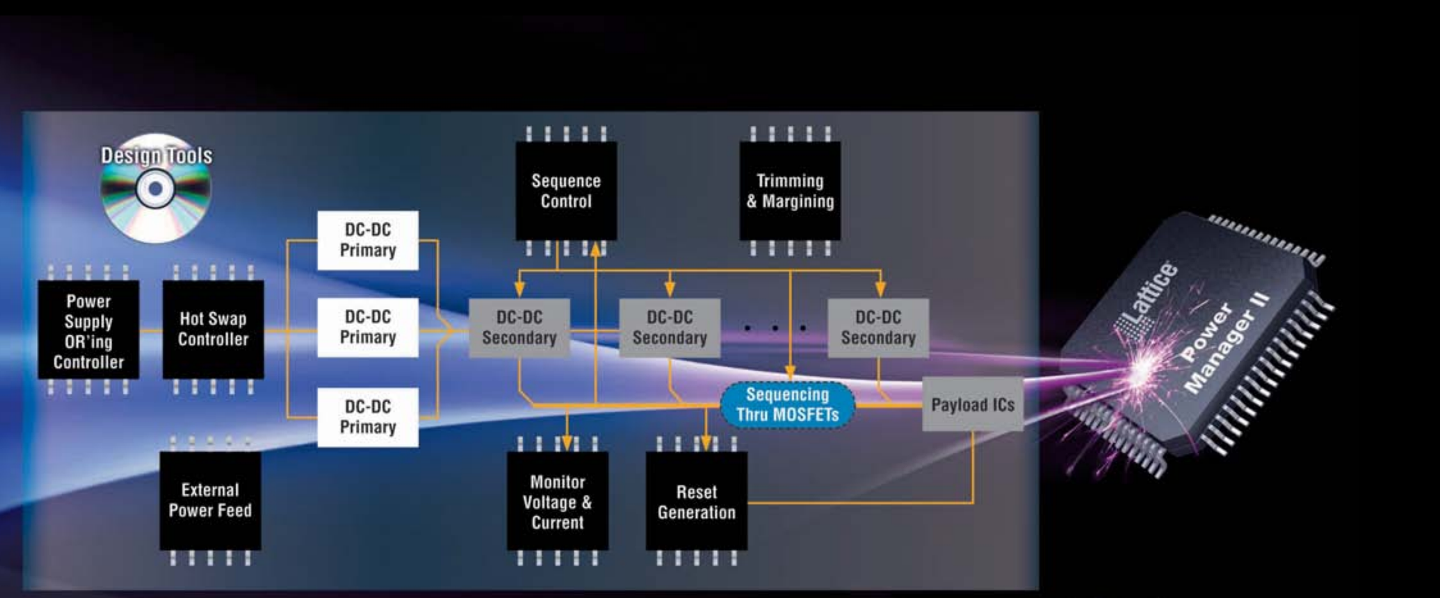
Power 2 You

A Guide to Power Supply Management and Control



Board Power Management Functions

LEARN HOW TO:
» Reduce Power Management Costs
» Increase System Reliability
» Reduce the Risk of Circuit Board Respins

Shyam Chandra

Lattice Semiconductor Corporation

Table of Contents

Power 2 You – Solutions Summary

Every circuit board is powered from one or more sources called the input, or primary, power supply. And, every circuit board performs one or more functions using a number of ICs, such as ASICs, CPUs, FPGAs, and so on. These ICs are called the payload ICs. The circuit board generates multiple power rails from the input supplies to power these payload ICs, using board mounted supplies called primary and secondary supplies. The term 'Power Management' in *Power 2 You* includes all power rail control functions implemented in a circuit board. Typically, input power rails are controlled by power management functions such as hot-swap control and redundant power rail control. On the payload side, power management functions include sequencing, monitoring, supervisory signal generation, trimming and margining.

The Lattice Semiconductor Power Manager II family of devices: ispPAC®-POWR1220AT8, ispPACPOWR1014A, ispPAC-POWR1014, ispPAC-POWR607 and ProcessorPM™-POWR605, are the industry-leading power management solutions. Power Manager II devices are configurable via PAC-Designer®, a free EDA tool available from www.latticesemi.com. In the PAC-Designer tool, circuit designs are entered graphically and then verified, all within the software environment.

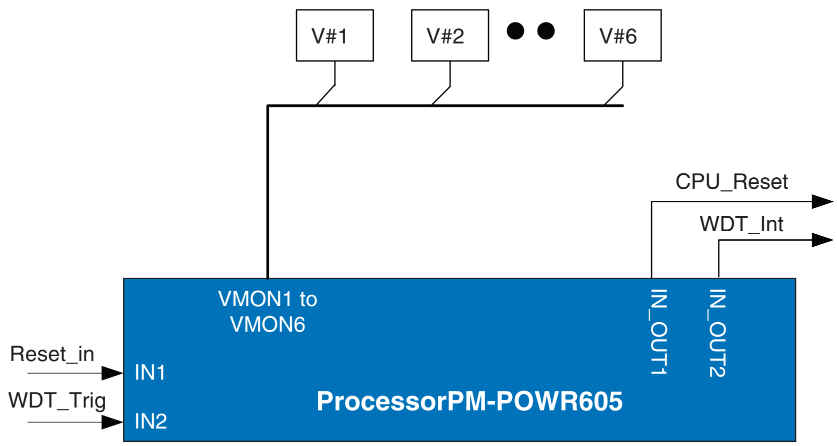
Complete and detailed descriptions of power management techniques using Power Manager II devices is available free from Lattice Semiconductor in a book entitled *Power 2 You*, at: http://www.latticesemi.com/p2y. The following is a summary of the contents of *Power 2 You*, with hyperlinks provided to relevant chapters in the book.

1. N-Supply Supervisor, Reset Generator and Watchdog Timer

Features of Supervisor, Reset Generator and Watchdog Timer in a Power Manager II Device

- Monitors up to 12 rails for over-voltage / under-voltage faults
- Precision (0.2% typ.) programmable monitoring threshold from 0.67V to 5.8V
- Differential voltage sensing for monitoring low voltage, high current supplies
- Fast fault detection with glitch filtering – up to 64µs
- Reset generation with programmable pulse stretch of up to hundreds of milliseconds
- Low voltage interrupt generation
- Manual reset input with programmable de-bounce period
- Watchdog timer with programmable time delay from hundreds of milliseconds to minutes
- Flexible watchdog timer interrupt / reset signal combinations
- All features can be changed after assembly through in-system programming
- Over-voltage protection and under-voltage lock-out
- Integrates additional functions such as sequencing, hot-swap, trimming and margining
- Measures voltage and current through I^2C

Figure 1. ProcessorPM-POWR605 Integrating 6-Supply Supervisor, Reset Generator and Watchdog Timer



Advantages of Supervisor, Reset Generator and Watchdog Timer in a Power Manager II Device

- Lowers cost compared to multiple supervisor and reset ICs
- Reduces number of components – No resistors to set threshold, no capacitors to set time delay
- Increases functional reliability – Very fast fault detection, higher monitoring precision, fewer components
- Reduces spurious supply fault interrupts due to supervisor monitoring threshold accuracy and filtering supply glitches
- Reduces risk – Accommodates changes to specs through programmability
- Reduces part types – Single chip can be used across a wide range of applications
- Protects board against over-voltage faults by initiating shut-down

A detailed circuit description of a design using ProcessorPM-POWR605 device is provided in "3.2 N-Supply Supervisor, Reset Generator and Watchdog" on page 3-10 of the *Power 2 You* book. www.latticesemi.com/p2y.

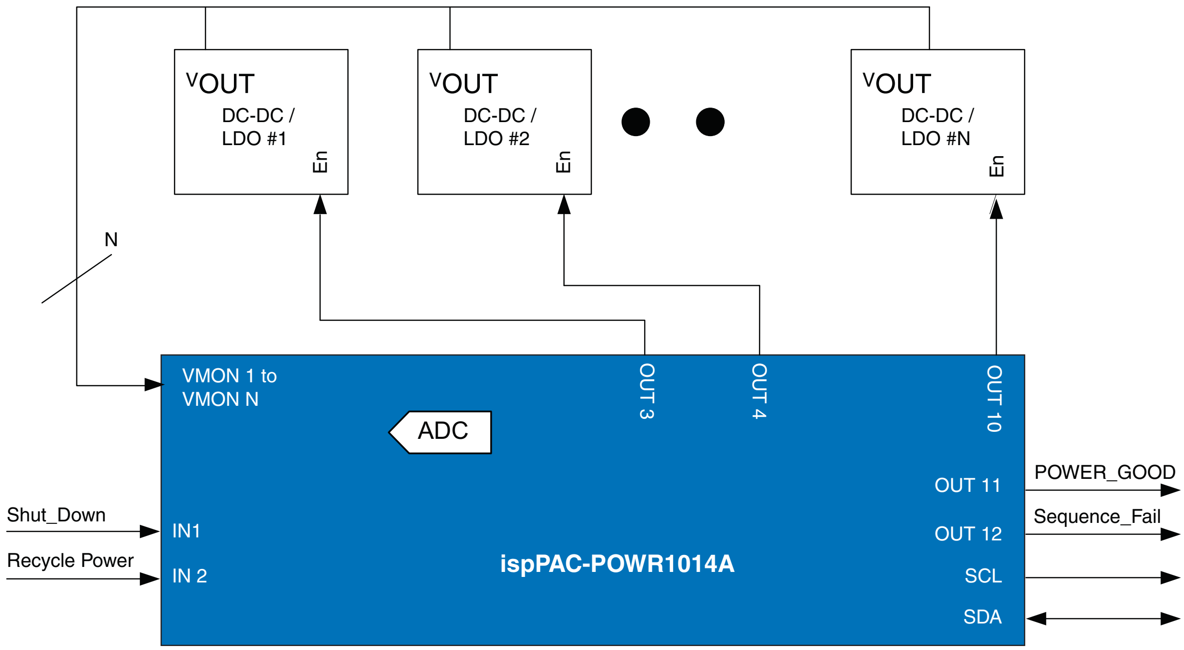
2. Power Supply Sequencing

Flexible N-Supply Sequencing

Features of Sequencer Implementation in a Power Manager II Device

- Programmable power up and power down sequencing
- Shutdown can be initiated through supply fault or an external input
- Allows user to change supply turn-on sequence or fine-tune sequence timing in software
- Supports multiple types of supply turn-on/off sequencing algorithms
- Closed loop sequencing / time-based open loop sequencing / complete sequencing within a given period
- Integrates additional functions such as supervision reset generation, watchdog timer, hot-swap, trimming and margining
- Measures voltage and current through I^2C
- Sequencing of supplies can be changed after assembly through in-system programming through JTAG

Figure 2. Flexible N-Supply Sequencing Using the ispPAC-POWR1014A Device



Advantages of Integrating Sequencer into a Power Manager II Device

- Reduces cost by integrating the sequencing function along with other board power management functions
- Minimizes the risk of board re-spin due to change of sequencing algorithm – Can adjust sequencing algorithm after board assembly
- Reduces first prototype board bring-up time – By providing additional debug flags such as sequence incomplete, supply turn-on timeout, etc.
- Increases board reliability by reducing the number of components – Does not require resistors or capacitors for timing or sequencing threshold adjustment
- Reduces the number of ICs required for power management, including sequencing, by meeting the sequencing requirements of a wide variety of boards

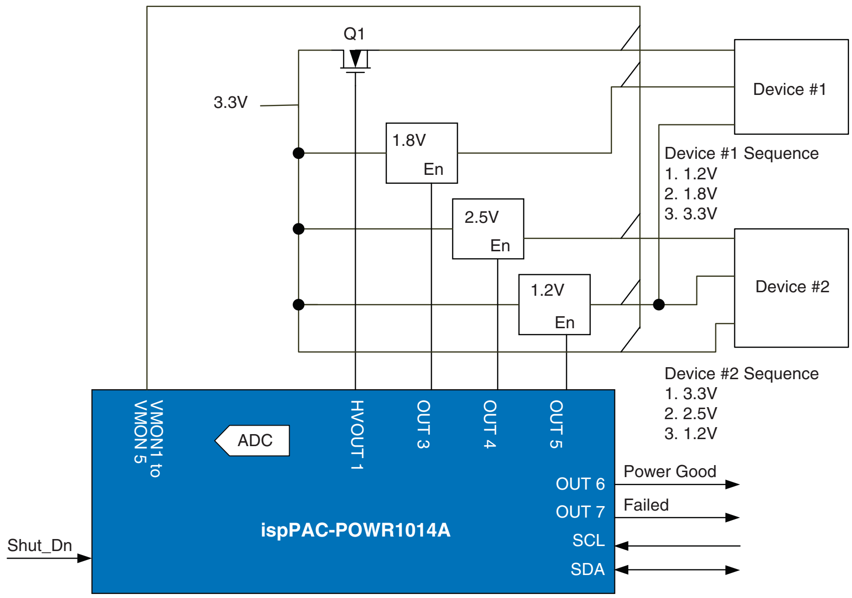
A detailed circuit description of a design using ProcessorPM-POWR605 device is provided in "4.2 Flexible N-Supply Sequencing Using Power Manager II Devices" on page 4-3 of the *Power 2 You* book.
www.latticesemi.com/p2y.

Sequencing with MOSFETs and DC-DC Enables

Features of Sequencer Implementation in a Power Manager II Device

- Integrates multiple charge pumps to control high-side N-Channel MOSFETs
- Has unified sequencing algorithm using MOSFETs and DC-DC converter enables
- Programmable power-up and power-down sequencing
- Shutdown can be initiated through supply fault or an external input
- Allows user to change supply turn-on sequence or fine-tune sequence timing in software
- Supports multiple types of supply turn-on/off sequencing algorithms:
- Closed loop sequencing / time-based open-loop sequencing / complete sequencing within a given period
- Integrates additional functions such as supervision reset generation, watchdog timer, hot-swap, trimming and margining
- Sequencing of supplies can be changed after assembly through in-system programming via JTAG
- Measures voltage and current through I^2C

Figure 3. The ispPAC-POWR1014A Implementing Sequencing with MOSFET and DC-DC Enables



Advantages of Integrating Sequencer into a Power Manager II Device

- Lowers cost by reducing the number of DC-DC converters as well as integrating sequencing function along with other board power management functions
- Minimizes the risk of board re-spin due to change of sequencing algorithm – Adjust sequencing algorithm after board assembly
- Reduces board bring-up time by providing additional debug flags such as sequence incomplete and supply turn-on timeout
- Increases board reliability by reducing the number of components – Does not require resistors or capacitors for timing or sequencing threshold adjustment
- Reduces the number of ICs required for power management, including sequencing by meeting the sequencing requirements of a wide variety of boards

A detailed circuit description is provided in "4.3 Sequencing With MOSFETs and DC-DC Converter Enables" on page 4-9 of the *Power 2 You* book. www.latticesemi.com/p2y.

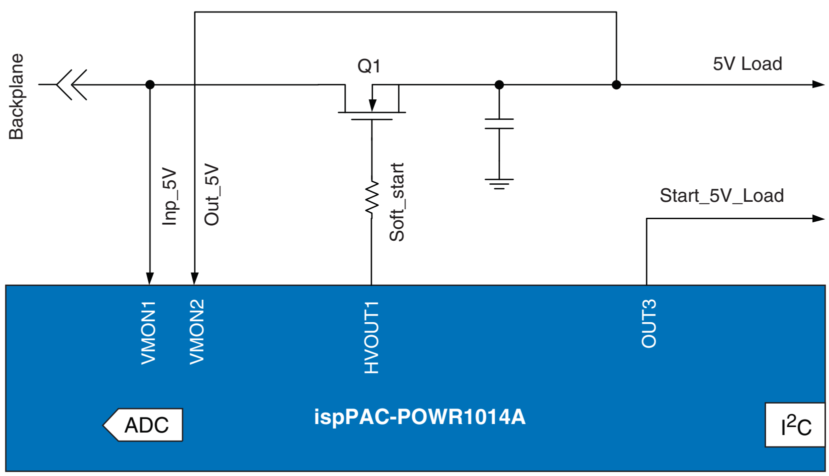
3. Hot-Swap Controllers

Hot-Swap Controller Using Soft-Start Mechanism

Features of Hot-Swap Controller Implementation in a Power Manager II Device

- Allows safe insertion into backplane – Programmable contact de-bounce delay
- Over-voltage protection and under-voltage lockout
- Controls inrush current through programmable soft-start rate feature
- Retry on fault with programmable retry period
- Backplane voltage status flag to secondary side
- Isolates board from backplane due to faults on board. Ramp time can be customized to meet board turn-on power requirements.
- Backplane voltage range 3V to 5V
- Integrate other board management functions such as sequencing, reset generation, supervision, watchdog timer, trimming and margining
- Measure backplane voltage in addition to other board voltages and currents through I^2C
- Management of supplies can be changed after assembly through in-system programming via JTAG
- Hot-swap controller can be programmed independently of other ICs on the board

Figure 4. Hot-Swap Control Implemented Through MOSFET Ramp Rate Control



Advantages of Integrating Hot-Swap Controller into a Power Manager II Device

- Lowers cost by integrating other board management functions and reducing the number of power management ICs
- Minimizes fault propagation to other boards in the system due to a fault on a circuit board
- Increases shut-down reliability – Ensures safe board shutdown through early warning to the secondary side
- Reduces the number of power management ICs – Integrates the remaining power management functions into the Power Manager II devices

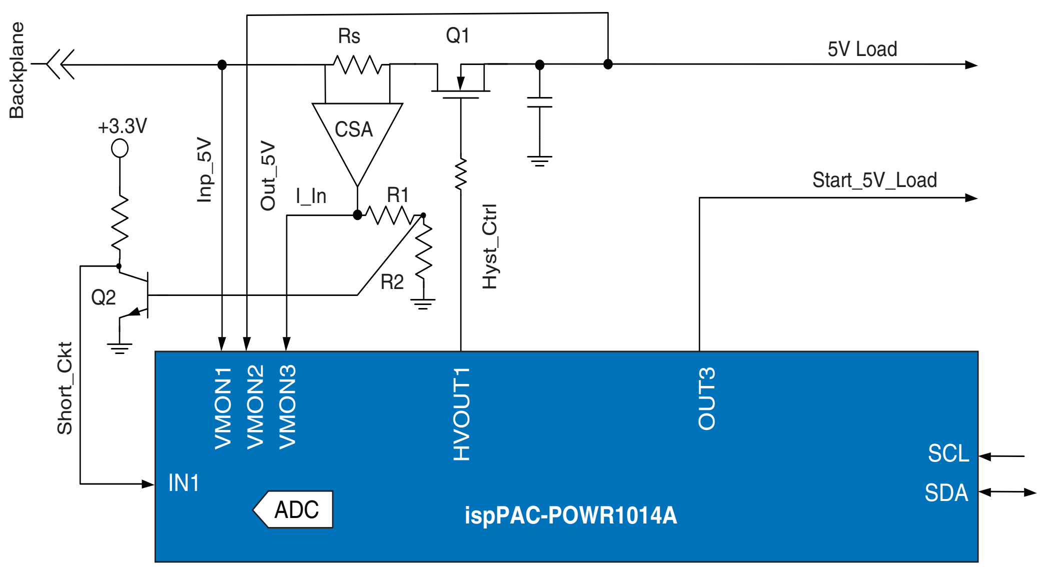
A detailed circuit description is provided in "Hot-Swap Controller Using Soft-start" on page 5-3 of the *Power 2 You* book. www.latticesemi.com/p2y.

Hot-Swap Controller with Hysteretic Current Limit Mechanism

Features of Hot-Swap Controller Implementation in a Power Manager II Device

- Limits the backplane current to a value during a current inrush event, minimizing power supply dip on the back-plane
- Two programmable over-current limits: hot-swap event and board operation
- Programmable contact de-bounce delay
- Over-voltage, over-current protection and under-voltage lockout
- Short circuit protection response < 1µs
- Programmable retry period
- Retry on hot-swap fault / secondary supply fault
- Early warning about the backplane voltage status to secondary side
- Isolates board from backplane due to faults on board
- Integrates other board management functions such as sequencing, reset generation, supervision, watchdog timer, trimming and margining
- Measures backplane voltage in addition to other board voltages and currents through I^2C
- Management of supplies can be changed after assembly through in-system programming via JTAG
- Hot-swap controller can be programmed independently of other ICs on the board

Figure 5. Hot-Swap Controller with Hysteretic Current Limit



Advantages of Hot-Swap Controller Integrated into a Power Manager II Device

- Reduces board cost by integrating other secondary board power management functions into Power Manager II
- Reduces board space taken up by the hot-swap controller by using a smaller hold-off capacitor
- Increases system reliability by reducing the peak current during the hot-swap event and during board fault
- Minimizes fault propagation to other boards in the system due to a fault on a circuit board
- Increases shut-down reliability – Ensures safe board shutdown through early warning to the secondary side
- Reduces the number of power management ICs – Integrates the remaining power management functions into the Power Manager II device

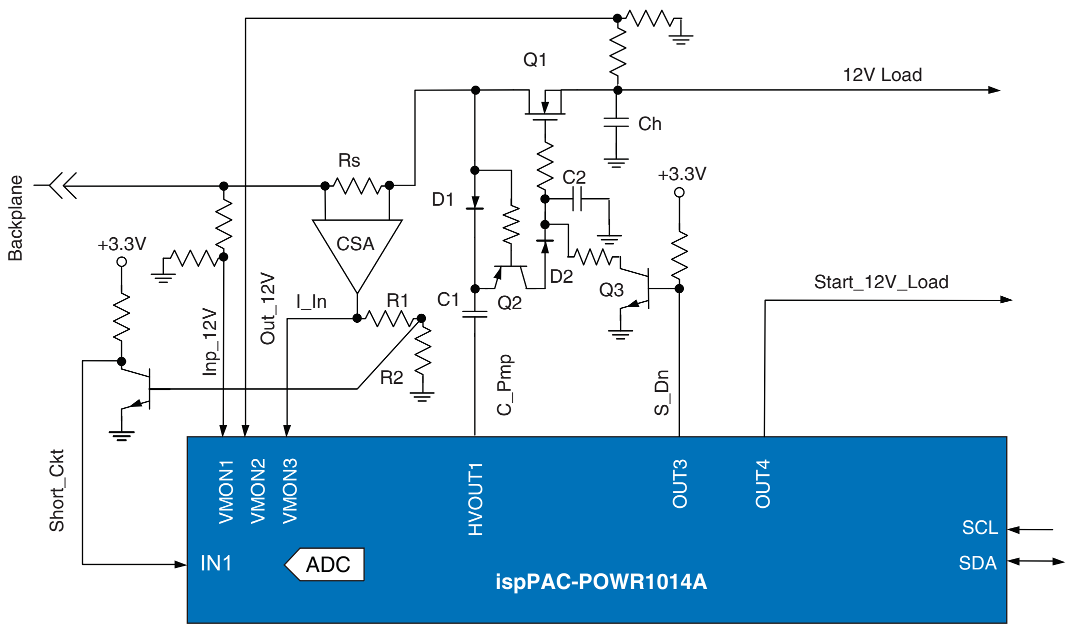
A detailed circuit description is provided in "Hot-Swap Controller with Hysteretic Current Limit Mechanism" on page 5-4 of the *Power 2 You* book.
www.latticesemi.com/p2y.

12V/24V Hot-Swap Controller

Features of Hot-Swap Controller Integrated into a Power Manager II Device

- Wide operating voltage range – 6V to 24V
- Can be used across a wide range of board power – 10W to 200W
- Limit the backplane current to a value during current inrush event to meet the safe operating area (SOA) specifications of a MOSFET
- Programmable inrush and operating over-current limits independently
- Programmable contact de-bounce delay
- Over-voltage, over-current protection and under-voltage lockout
- Short circuit protection response < 1µs
- Programmable retry period
- Retry on hot-swap fault/ secondary supply fault
- Backplane fault early warning
- Isolates board from backplane due to faults on board
- Integrates other board management functions such as sequencing, reset generation, supervision, watchdog timer, trimming and margining.
- Measures backplane voltage in addition to other board voltages and currents through I^2C
- Management of supplies can be changed after assembly through in-system programming via JTAG
- Hot-swap controller can be programmed independently of other ICs on the board

Figure 6. 12V/24V Hot-Swap Controller Using an ispPAC-POWR1014A Device



Advantages of Hot-Swap Controller Integrated Into a Power Manager II Device

- Reduces board cost by integrating other secondary board power management functions into Power Manager II, lower cost MOSFET and smaller hold-off capacitor
- Reduces board space due to smaller hold-off capacitor
- Increases system reliability by reducing the peak current during the hot-swap event as during board fault
- Minimizes fault propagation to other boards in the system due to a fault on a circuit board
- Increases shut-down reliability – Ensures safe board shutdown through early warning to the secondary side
- Reduces the number of power management ICs – Integrates the remaining power management functions into the Power Manager II device

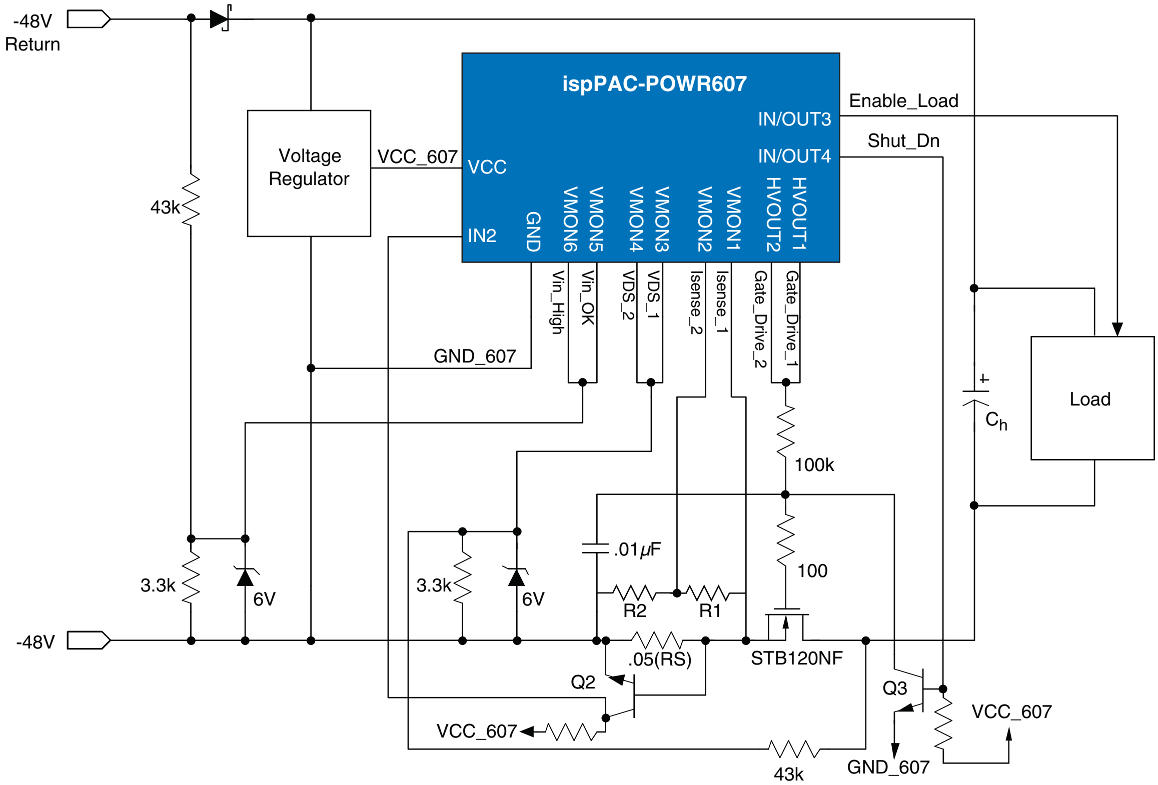
A detailed circuit description is provided in "12V/24V Hot-Swap Controller" on page 5-8 on page 5-2 of the *Power 2 You* book. www.latticesemi.com/p2y.

Negative Supply Hot-Swap Controller

Features of the Negative Supply Hot-Swap Controller Implementation

- Wide operating voltage range: -35V to -80V
- Supports wide range of board power: 10W to 200W
- Deterministic current level during hot-swap to meet the SOA specifications of a MOSFET
- Programmable inrush current limit
- Programmable over-current limit
- Short circuit protection response time < 1µs
- Programmable contact de-bounce delay
- Over-voltage protection and under-voltage lockout
- Enables load after the hot-swap event, further minimizing inrush current
- Programmable retry period
- Control of hot-swap from the secondary side
- Early fault warning to secondary side
- Immune to 100V glitches

Figure 7. Hot-Swap Controller Circuit Using an ispPAC-POWR607 Device



Advantages of Hot-Swap Controller Integrated into a Power Manager II Device

Increases system reliability by:

- Limiting inrush current to the programmed value
- Limiting current due to secondary side faults to the programmed value
- Reducing current glitches on the backplane
- Reducing power stress on the MOSFET
- Minimizes fault propagation through the system from a faulty card
- Reducing overall system cost
- Reducing board space due to smaller hold-off capacitor
- Reducing the number of hot-swap controller types across multiple projects

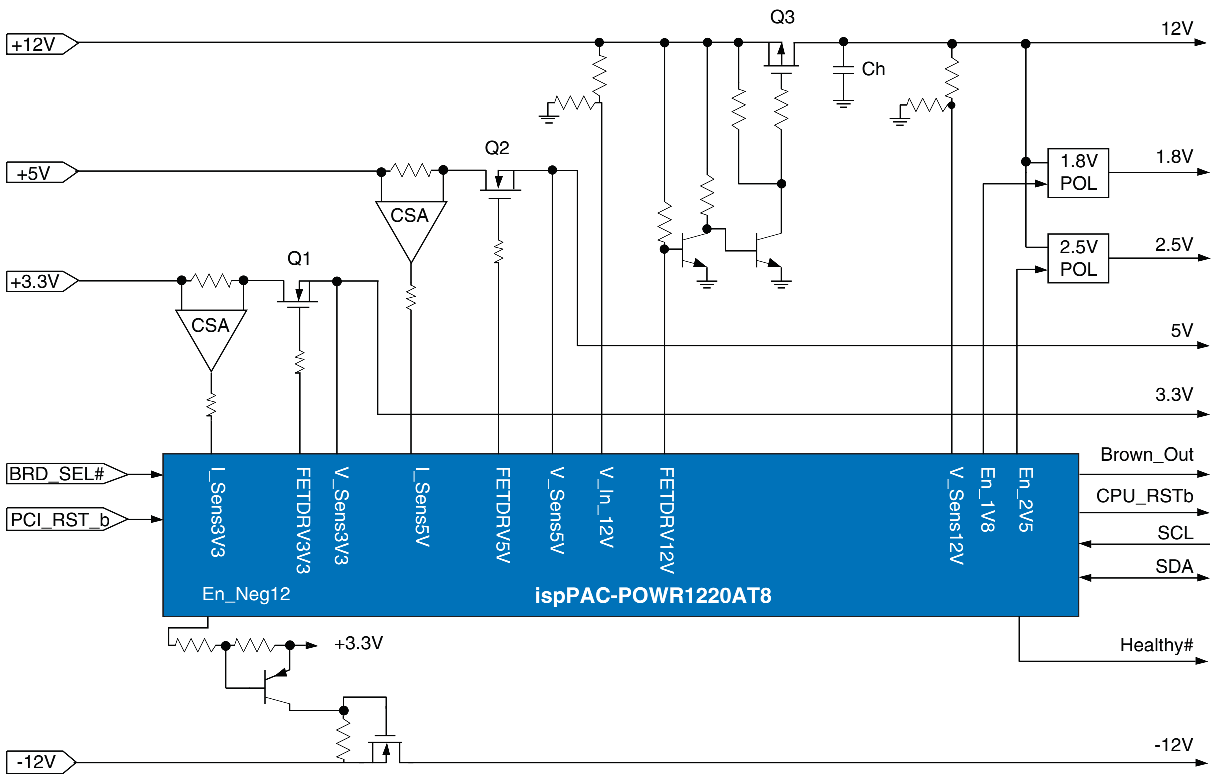
A detailed circuit description is provided in "5.3 Implementing a Negative Supply Hot-Swap Controller" on page 5-13 of the *Power 2 You* book. www.latticesemi.com/p2y.

CompactPCI Board Management

Features of CompactPCI Board Management Controller Integrated into a Power Manager II Device

- Hot-swap for 3.3V, 5V, ±12V (CompactPCI hot-swap and board controller)
- Can be used across a wide range of board power – 10W to 200W
- Programmable inrush current per individual rail
- Programmable contact de-bounce delay on all supply inputs
- Over-voltage, over-current protection and under-voltage lockout
- Short circuit protection response < 1µs
- Programmable retry period – Retry on hot-swap fault / secondary supply fault
- Backplane fault early warning
- Isolates board from backplane due to faults on board
- Integrate other board management functions such as sequencing, reset generation, supervision, watchdog timer, trimming and margining.
- Measures backplane voltages in addition to other board voltages and currents through I^2C
- Management of supplies can be changed after assembly through in-system programming via JTAG

Figure 8. An ispPAC-POWR1220AT8 Device – Complete CompactPCI Board Management



Advantages of CompactPCI Board Management Integrated into a Power Manager II Device

- Reduces board cost by integrating other secondary board power management functions into Power Manager II, lower cost MOSFET and smaller hold-off capacitor
- Increases system reliability by reducing the peak current during the hot-swap event as well as during board fault
- Minimizes fault propagation to other boards in the system due to a fault on a circuit board
- Increases shut-down reliability – Ensures safe board shutdown through early warning to the secondary side
- Reduces the number of power management ICs – Integrates the remaining power management functions into the Power Manager II device

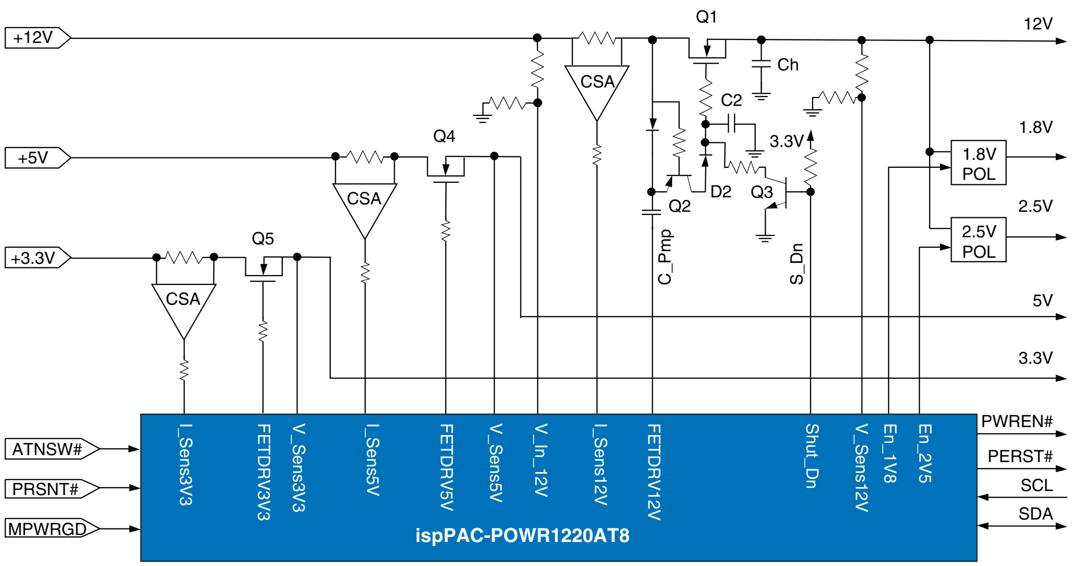
A detailed circuit description is provided in "5.4 CompactPCI Board Management" on page 5-16 of the *Power 2 You* book. www.latticesemi.com/p2y.

CompactPCI Express Board Management

Advantages of CompactPCI Express Board Management

- Hot-swap for 3.3V, 5V, +12V (CompactPCI Express, VME system board controller)
- Can be used across a wide range of board power – 10W to 200W
- Programmable inrush current per individual rail
- Programmable contact de-bounce delay on all supply inputs
- Over-voltage, over-current protection and under-voltage lockout
- Short circuit protection response < 1µs
- Programmable retry period – Retry on hot-swap fault / secondary supply fault
- Backplane fault early warning
- Isolates board from backplane due to faults on board
- Integrates other board management functions such as sequencing, reset generation, supervision, watchdog timer, trimming and margining.
- Measures backplane voltages in addition to other board voltages and currents through I^2C
- Management of supplies can be changed after assembly through in-system programming via JTAG

Figure 9. Complete CompactPCI Express Board Power Management



Advantages of CompactPCI Express Board Management Implementation

- Reduces board cost by integrating other secondary board power management functions into Power Manager II, lower cost MOSFET and smaller hold-off capacitor
- Increases system reliability by reducing the peak current during the hot-swap event as well as during board fault
- Minimizes fault propagation to other boards in the system due to a fault on a circuit board
- Increases shut-down reliability – Ensures safe board shutdown through early warning to the secondary side
- Reduces the number of power management ICs – Integrates the remaining power management functions into the Power Manager II device

A detailed circuit description is provided in "CompactPCI Express Board Management" on page 5-19 of the *Power 2 You* book. www.latticesemi.com/p2y.

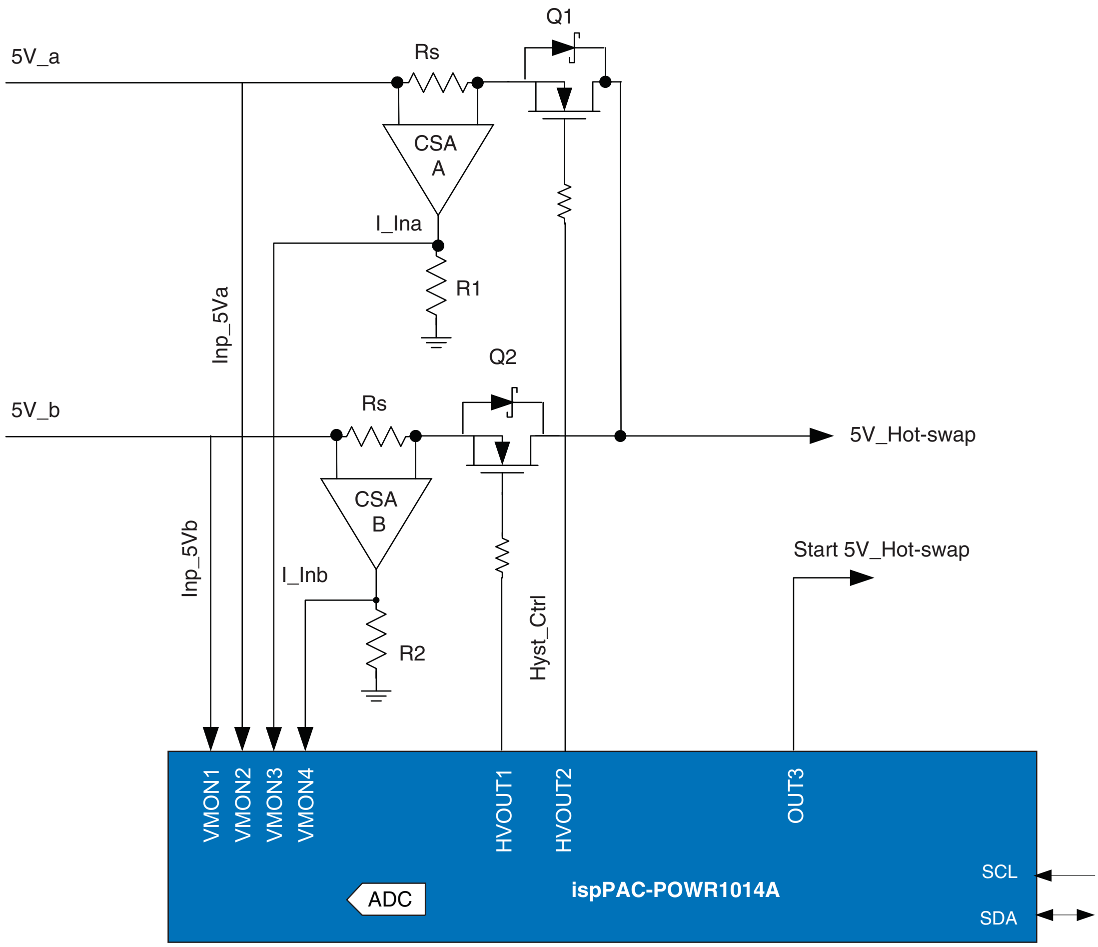
4. Redundant Supply Management

Two Rail 5V Power Supply Or'ing (Using MOSFETs)

Features of Power Manager II-Based Implementation

- Low power loss replacement for diode
- Uses N-Channel MOSFET
- Proactive reverse current protection
- Under-voltage and over-voltage protection
- Individual branch current and voltage measurement through I^2C
- Integrates other board management functions such as hot-swap, supply sequencing, voltage supervision, reset generation, watchdog timer, trimming and margining

Figure 10. An ispPAC-POWR1014A Device Implementing Two-Rail 5V OR'ing Control



Advantages of Integrating Power OR'ing Control into a Power Manager II Device

- Increases board reliability through proactive reverse current protection
- Lowers power management cost through integrating multiple power management functions into a single device
- Reduces the number of ICs required to implement the Power OR'ing feature

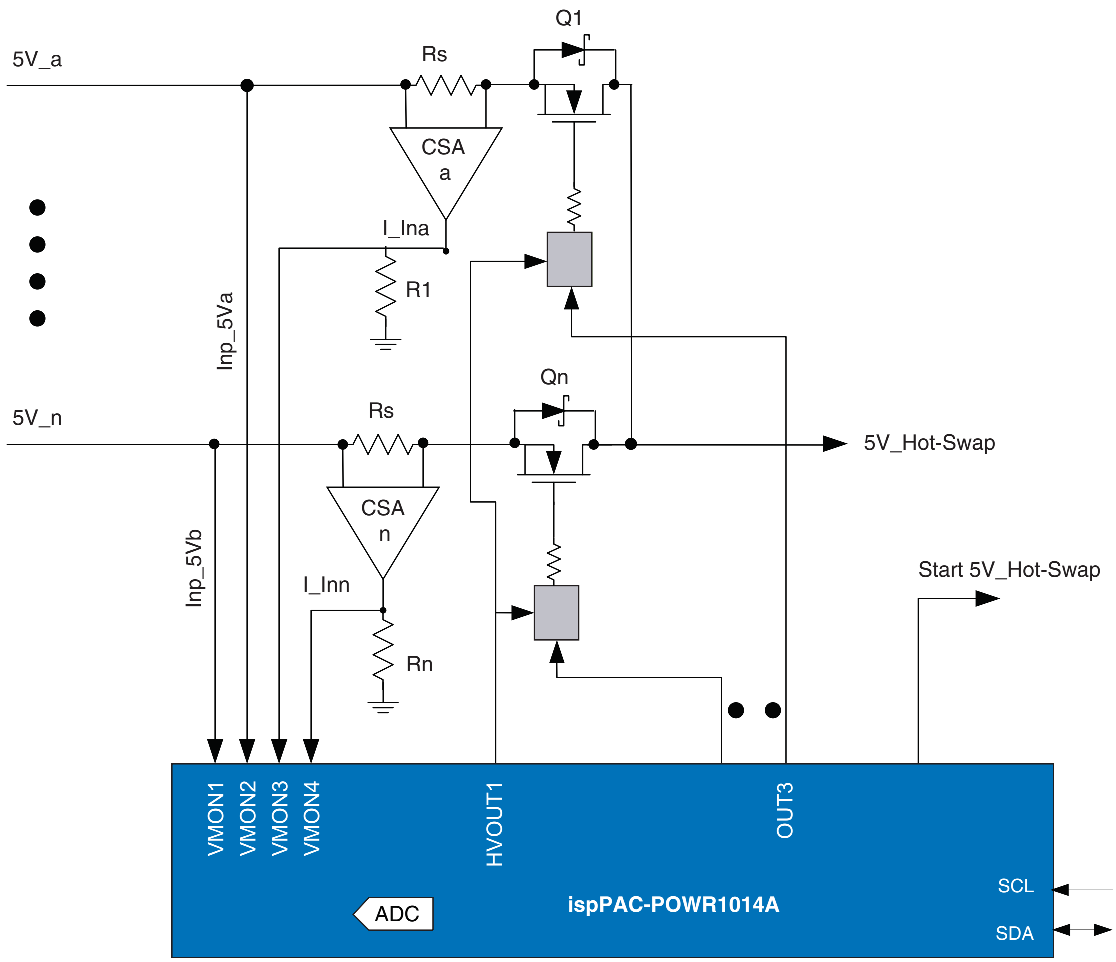
A detailed circuit description is provided in "6.3 +5v Power Supply Or'ing (Using MOSFETs) Circuit" on page 6-3 of the *Power 2 You* book. www.latticesemi.com/p2y.

Power Supply OR'ing of N-Rails Using MOSFETS

Features of Power Manager II-Based Implementation

- Single Power Manager II chip implements OR'ing up to six channels
- Low power loss replacement for diode
- Uses N-Channel MOSFET
- Proactive reverse current protection
- Under-voltage and over-voltage protection
- Individual branch current and voltage measurement through I^2C
- Integrate other board management functions such as hot-swap, supply sequencing, voltage supervision, reset generation, watchdog timer, trimming and margining

Figure 11. N-Channel OR'ing through MOSFETS



Advantages of Integrating Power OR’ing Control into a Power Manager II Device

- Increases board reliability through proactive reverse current protection
- Lowers power management cost through integrating multiple power management functions into a single device
- Reduces number of ICs required to implement Power OR’ing feature

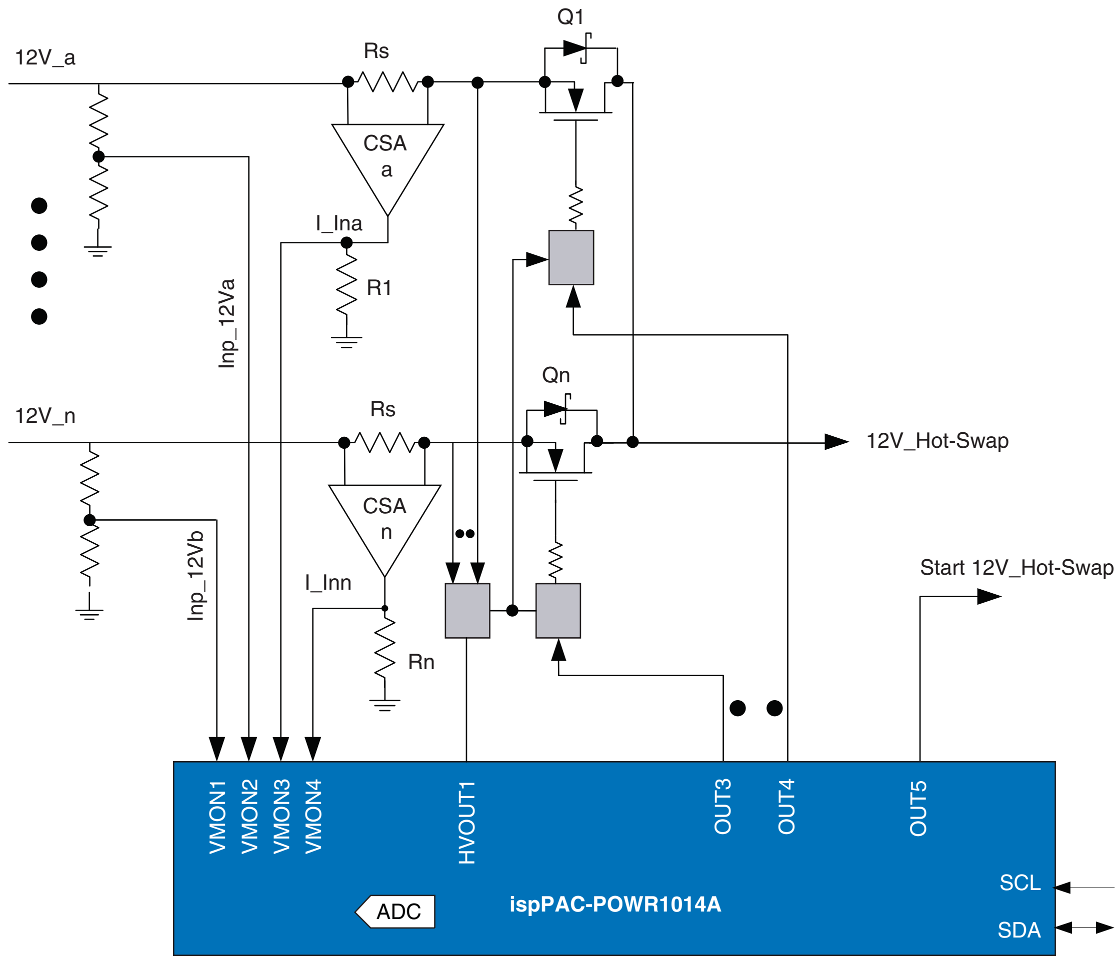
A detailed circuit description is provided in “6.4 Power Supply OR’ing of Three or More 5V Supply Rails Using MOSFETS” on page 6-5 of the *Power 2 You* book.
www.latticesemi.com/p2y.

N-rail (12V/24V) OR’ing

Features of Power Manager II-Based Implementation

- Wide operating voltage range: 6V to 24V
- Single Power Manager II chip implements OR’ing up to six channels
- Low power loss replacement for diode
- Uses N-Channel MOSFET
- Proactive reverse current protection
- Under-voltage and over-voltage protection
- Individual branch current and voltage measurement through I^2C
- Integrates other board management functions such as hot-swap, supply sequencing, voltage supervision, reset generation, watchdog timer, trimming and margining

Figure 12. N- 12V Rail OR'ing Through MOSFET Using an ispPAC-POWR1014A Device



Advantages of Integrating Power OR'ing Control into a Power Manager II Device

- Increases board reliability through proactive reverse current protection
- Lowers power management cost through integrating multiple power management functions into a single device
- Reduces number of ICs required to implement the Power OR'ing feature

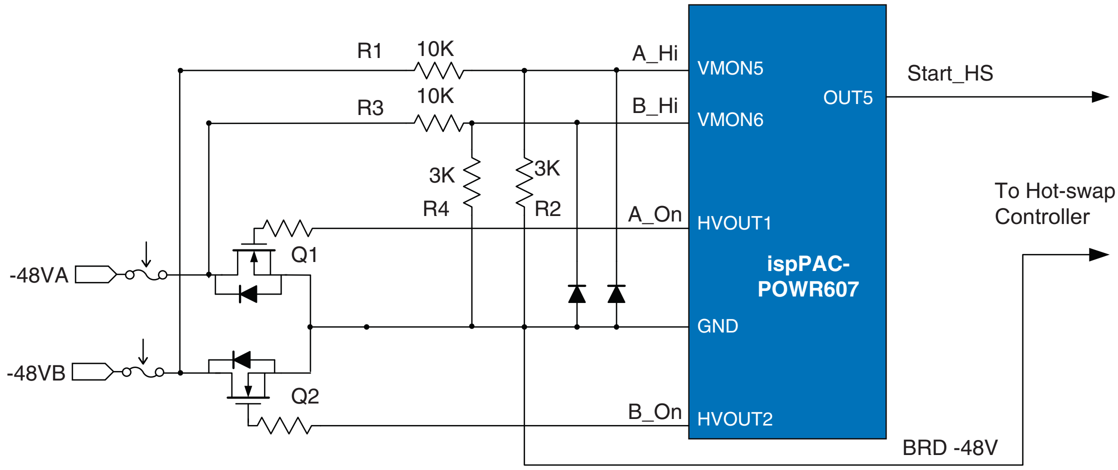
A detailed circuit description is provided in "6.5 N-rail (12V/24V) OR'ing" on page 6-7 of the *Power 2 You* book. www.latticesemi.com/p2y.

-48V Supply OR'ing Through MOSFETS

Features of Power Manager II-Based Implementation

- Wide operating voltage range: -30V to -80V
- Low power loss replacement for diode
- Uses N-Channel MOSFET
- Hot-swappable
- Proactive reverse current protection
- Under-voltage and over-voltage protection
- Fuse fault detection
- Controls hot-swap controller

Figure 13. Dual -48V MOSFET OR'ing Circuit Using an ispPAC-POWR607 Device



Advantages of Integrating Power OR'ing Control into a Power Manager II Device

- Increases board reliability through proactive reverse current protection
- Lowers power management cost through integrating power OR'ing along with voltage monitoring and contact de-bouncing
- Reduces number of ICs required to implement the Power OR'ing feature

A detailed circuit description is provided in "6.6 -48V Supply OR'ing Through MOSFETS" on page 6-10 of the *Power 2 You* book. www.latticesemi.com/p2y.

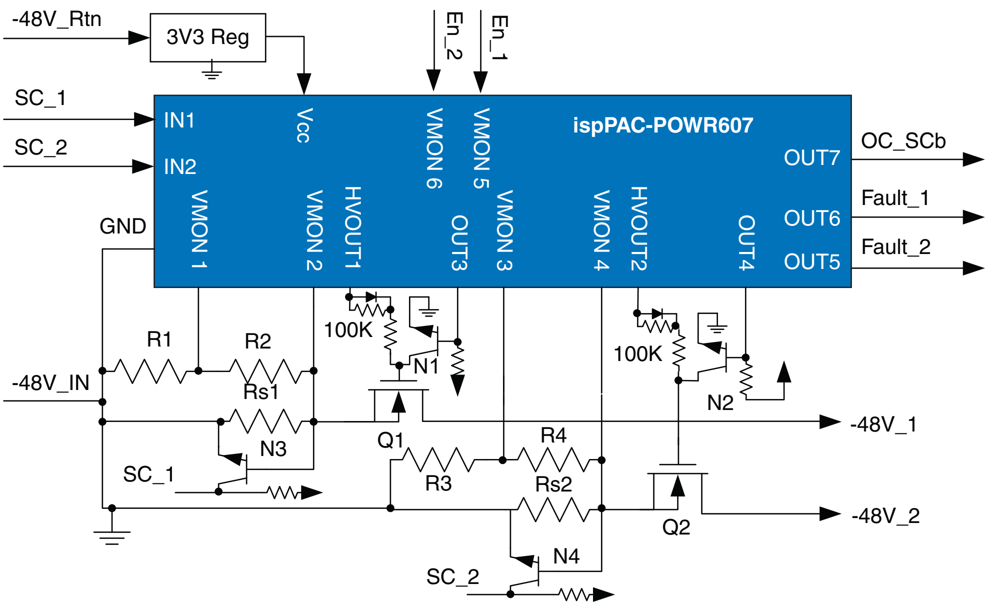
5. Power Feed Controllers

Dual Rail -48V Power Feed Controller

Features of Power Manager II-Based Implementation

- Wide operating voltage range: -30V to -80V
- Safe MOSFETs operation (SOA)
- Individual channel current limiting
- Individual channel short circuit protection - < 1µs response time
- No-current and over-current flags per output branch
- Individual channel enables
- Retry upon fault detection
- Filters out short period over-current glitches

Figure 14. An ispPAC-POWR607 Implements a Two-Channel -48V Power Feed Circuit



Advantages of Integrating 2-Channel -48V Power Feed into a Power Manager II

- Lowers cost by integrating two-channel power feed into a single chip
- Increases board reliability through current limiting and short circuit protection on a per-channel basis
- Reduces the number of ICs by being able to be customized across a wide range of power feed and protection requirements

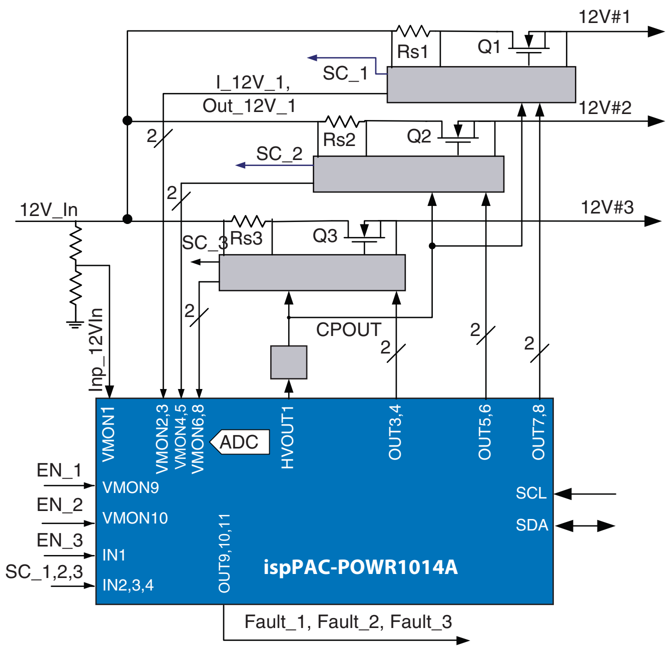
A detailed circuit description is provided in "7.2 Dual Rail -48V Supply Feed" on page 7-1 of the *Power 2 You* book. www.latticesemi.com/p2y.

Three-Channels of a 6V-24V Power Feed System

Features of Power Manager II-Based implementation

- Wide operating voltage range: 6V to 24V
- Expandable up to four channels of power feed control
- Safe MOSFET operation (SOA)
- Individual channel current limiting
- Individual channel short circuit protection - < 1µs response time
- No-current and over-current flags per output branch
- Individual channel enables
- Retry upon fault detection
- Filters out short period over-current glitches
- Individual channel current and voltage measurement through I^2C
- Integrates other board power management functions

Figure 15. Three-Channel 12V Power Feed Circuit



Advantages of Integrating Multiple Channel Power Feed into a Power Manager II Device

- Reduces cost of implementation by reducing the number of ICs required for the entire power feed circuit
- Reduced number of power feed ICs – Customizable to meet power feed characteristics across a wide variety of applications
- Increased reliability of the board by integrating other board management functions such as sequencing, reset generation, etc.

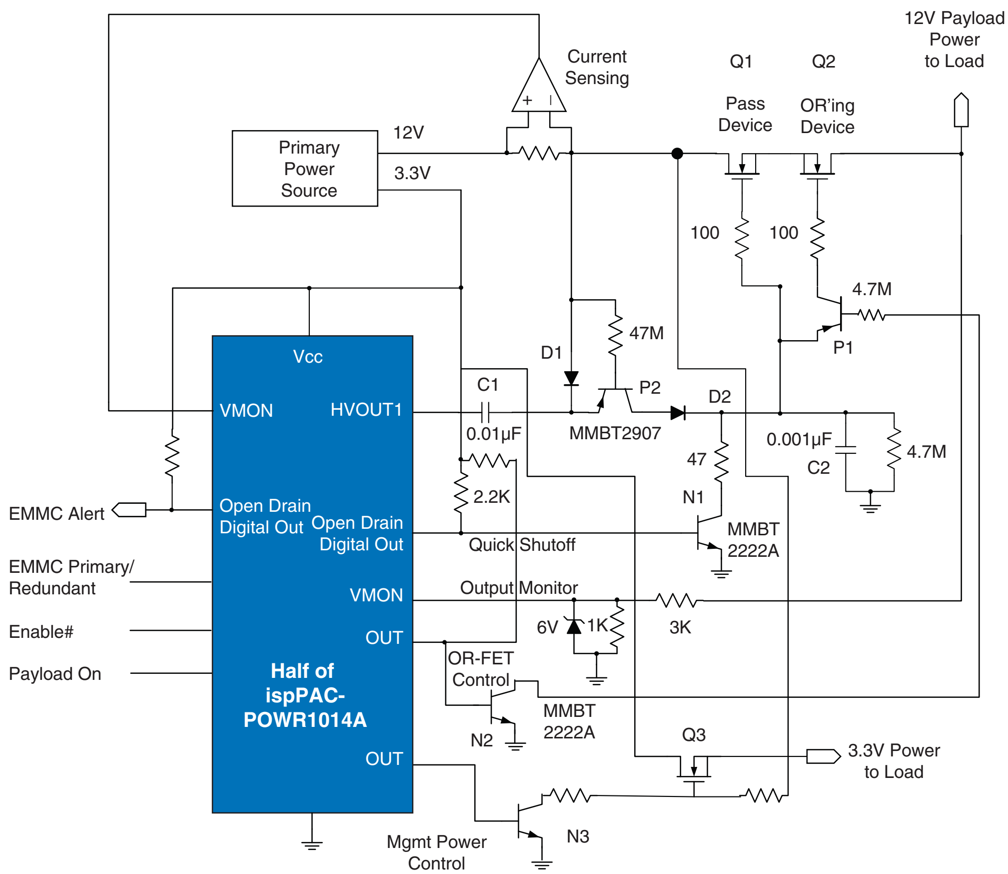
A detailed circuit description is provided in "7.3 Three Channels of a +12V Power Feed System" on page 7-4 of the *Power 2 You* book. www.latticesemi.com/p2y.

Two-Channel +12V & 3.3V Power Feed With Diode OR'ing

Features of the Power Feed Solution Integrated into Power Manager II

- Designed for use in MicroTCA Power Module – Two channels
- Feeds 3.3V and 12V with OR'ing support using MOSFET
- Turns off 12V power feed within 50µs of AMC card extraction
- Programmable over-current protection
- MOSFET operates in safe operating area
- Supports OR'ing of payload power supply rails (+12V)
- Proactive reverse current protection
- Measures voltage and current through I^2C
- Monitors input 12V supply for over- and under-voltage conditions
- Expand up to four channels of power feed as well as trimming of 12V supply for power supply OR'ing function

Figure 16. One-Channel uTCA Power Feed Using Half of an ispPAC-POWR104A Device



Advantages of Two-Channel MicroTCA Power Feed Circuit Using a Power Manager Device:

- Lowers cost of implementation
- Increased reliability through high precision voltage monitoring
- Integrates more channels of power feed circuitry along with trimming features

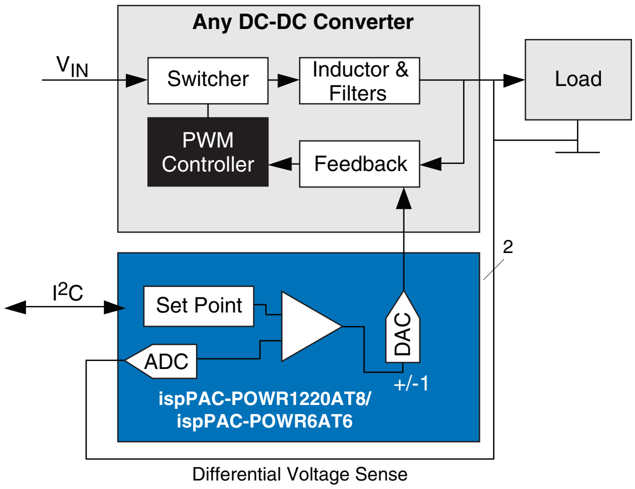
A detailed circuit description is provided in "7.4 2-Channel +12V & 3.3V Power Feed With MOSFET OR'ing" on page 7-8 of the *Power 2 You* book. www.latticesemi.com/p2y.

6. Trimming and Margining

Features of Closed Loop Trimming and Margining Implemented in a Power Manager II Device

- Ideally suited for trimming any low voltage (<1.2V) and high current analog DC-DC converter
- Output voltage accuracy = Set pin voltage ±10mV
- Single chip supports up to eight channels of trimming and margining
- Voltage margining support
- Differential voltage sensing
- Voltage scaling
- VID support through simple PLD
- Integrates trimming and margining along with voltage supervision, sequencing, reset generation and hot-swap controller functions

Figure 17. Low Cost Trimming and Margining Solution Using Power Manager II



Result: Voltage Error <1% At Load! (-40° to +85° C)

Advantages of Implementing Trimming and Margining Using a Power Manager II Device

- Lowers cost of a DC-DC converter - No need for Digital DC-DC converter to support margining and trimming
- Increases functional reliability through DC-DC converter precision output voltage control
- Reduces operating power through voltage scaling
- Reduces debug time by automated margining tests

A detailed circuit description is provided in “8.4 Trimming and Margining – Principle of Operation” on page 8-3 of the *Power 2 You* book. www.latticesemi.com/p2y.

About the Author

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Prior to joining Lattice, Shyam worked for Vantis and AMD in sales and applications and previously was a telecom design engineer with Indian Telephone Industries. Shyam received his Masters degree in Electrical Engineering from the Indian Institute of Technology, Madras.

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